United States
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General
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Eastern White Pine: Today and Tomorrow

Symposium Proceedings

FOREWORD

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The Symposium "Eastern White Pine: Today and Tomorrow" was held in Durham, New Hampshire, June 12-14, 1985. The organizing committee was chaired by Theodore Howard of the University of New Hampshire and included Richard Weyrick, also of UNH, and M. E. Demeritt, David Funk, Kenneth Lancaster, William Leak, and Carl Tubbs of the USDA-Forest Service. The Symposium was cosponsored by the UNH Department of Forest Resources, the USDA Northeastern Forest Experiment Station and Northeastern Area State and Private Forestry, the Society of American Foresters Economics and Policy Working Group, and the Ruth E. Farrington Forestry Fund.

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Sponsored by:

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ABSTRACTS OF POSTER PRESENTATIONS

OPENING REMARKS FOR WHITE PINE SYMPOSIUM

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On behalf of Station Director Denver Burns, I welcome you to the Eastern White Pine Symposium. I am happy to be here on the University of New Hampshire campus both to attend this symposium and because it is the location for the Forest Service's Louis C. Wyman Forestry Sciences Laboratory. The Laboratory's staff includes both researchers and state and private forestry experts. We enjoy excellent cooperative working arrangements with the forestry department and several other departments on campus. We have been on the UNH campus since 1966 and in our own laboratory since 1971. I invite you to visit the Laboratory, which is located at the intersection of Mast and Concord Roads west of Durham.

We are pleased to participate in this symposium about white pine, a species associated with the "old days" of logging in the Northeast and the Lake States. White pine contributed much to the development of this Nation and also provides a great deal of material for the Forest History magazine.

Once the large, old white pine stands were harvested, the white pine weevil and blister rust were reasons not to expect much from white pine. However, despite (or maybe because of) human indifference, white pine made an amazing comeback. I believe nearly every forester and ecologist has studied or is aware of how white pine comes in on abandoned fields. It is a classic example of secondary succession. And now we have the opportunity to again examine the white pine resource...after all, there are about 4 1/2 million acres of white pine out there. Some of the information I have seen recently about white pine is striking. I offer these items:

** In New Hampshire, between 1973 and 1983, 179,000 acres of white pine have been lost from the type. These were mostly young stands that were taken by urban expansion or converted into hardwoods, primarily red maple.

** The Monongahela National Forest in West Virginia has approximately 10,000 acres of planted and natural white pine, and the acreage is increasing.

** White pine substantially outgrows most of our hardwoods. For example, 100-year-old unmanaged stands of white pine on Site Index 60 will outgrow and outproduce hardwood trees by about 6 to 1.

** In Ohio, one company is converting about 30,000 acres of hardwoods to conifers, with white pine a principal species in that conversion.

** In Illinois, the Shawnee National Forest recently established a white pine seed orchard to provide improved seed for four National Forests.

** The last stop on Friday's field trip is the Massabesic Experimental Forest, where we will have an opportunity to examine an old Station study comparing weevil incidence and height growth of western and eastern white pine.

So it is clear that white pine is on the minds of many resource managers. This Symposium is well timed and the results, I believe, are eagerly awaited. I hope, as the Symposium proceeds, that the research needs will be clearly identified, and the opportunities for technology transfer obvious. The Forest Service, both Research and State and Private Forestry, is proud to cosponsor this Symposium. We volunteered to publish the Proceedings because we all need the information compiled for this Symposium to do the best possible job of managing this extremely valuable resource. Thank you for the opportunity to participate, and on with the Symposium.

WHITE PINE: THE CASE FOR OPTIMISM

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Pine stumpage and lumber markets are changing, providing an increased incentive for growing and marketing higher grade logs. Because of poor log markets and inadequate management, pine quality is poor and the resource is underutilized. Because of its high inherent growth potential, white pine stands on good sites offer extraordinary financial opportunities. In contrarian[1] terms, they are an undervalued investment opportunity. While pests cannot be ignored, they can be dealt with and should not prevent active management of the 1.5-million-acre pine resource and the large volumes in mixed stands. The potential for growing pine in mixed and multistoried stands is underrated.

Today I will argue the case for optimism on the part of land managers who intend to pursue aggressive management of white pine. I'm arguing a classic contrarian case. Pine stands on good sites, and their future productive potential, are undervalued assets today and will continue to be for some time. This creates an opportunity for alert landowners to create wealth for themselves while upgrading the forest. They can be secure in the feeling that they will have little competition. Who wouldn't envy such a position?

This is not the same thing as optomism for the total white pine resource. In fact, my case rests on the poor condition of the existing resource and on the limited prospects for improvement in that condition.

First, I review the changing pine lumber and stumpage market. Next, I'll describe summary measures of what most people are doing with the pine resource, and summarize the silvicultural economics of pine. I'll list some illusions that have muddled people's thinking.

A Changing Pine Market

Pine took its early place in the Northeast's economy as a specialty species, valued for masts, spars, and wide boards. When the colonists wanted to placate the King, they shipped him a boatload of mast pines. Pine then became a major industrial commodity and a staple resource for sawmills. They moved from Maine and swept across the Mid-Atlantic states and the Great Lakes. White pine lumber reached the astounding peak output of 9.4 billion board feet in 1899 (Maine peaked sooner). Pine's peak output, then, was history when U.S. lumber hit its 1909 peak (Figs. 1 and 2). By then, much of the Northeast's pine was servicing the boxboard market.

Figure 1.

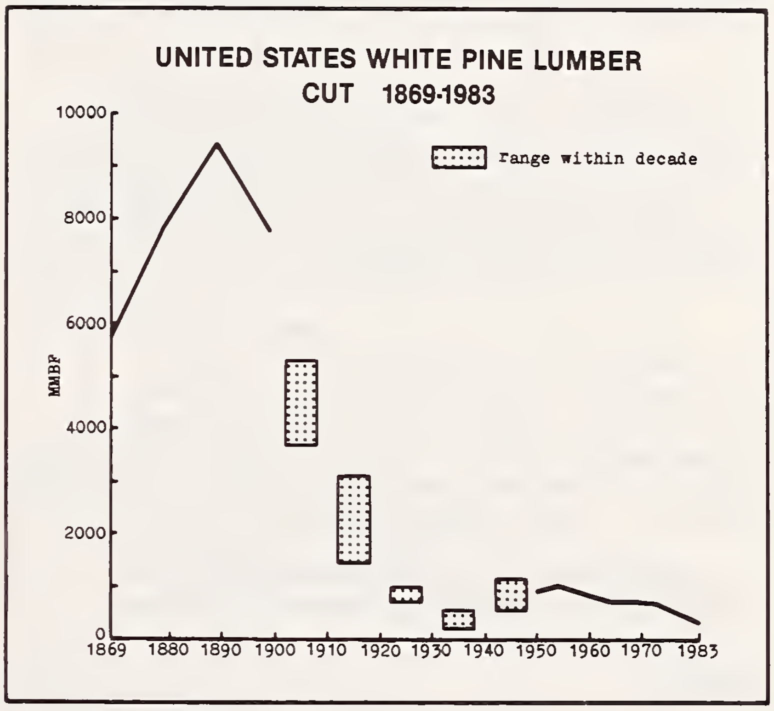
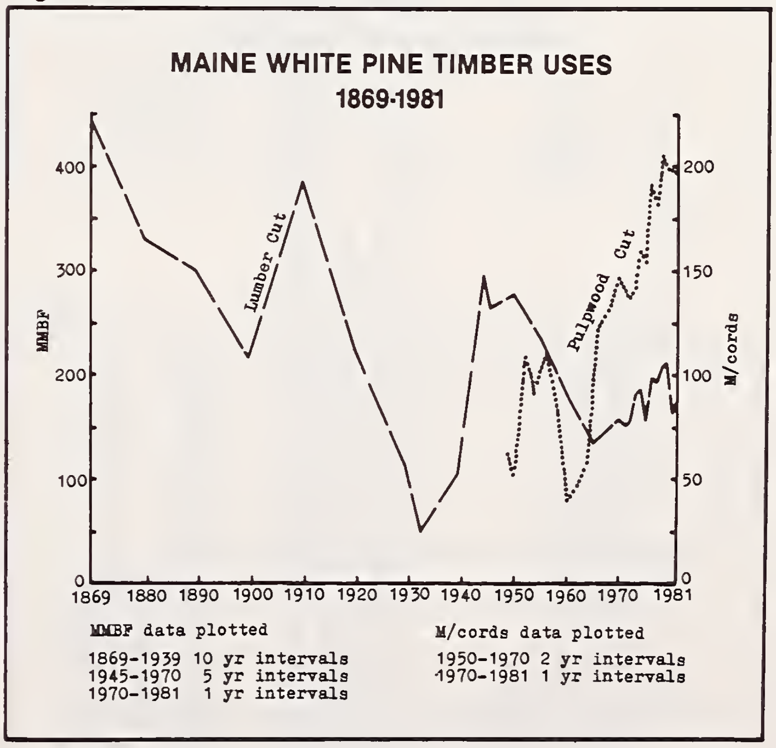


Figure 2.



There is a disadvantage to being a staple industrial commodity: You have to compete with everybody else who's liquidating timber, sometimes at a potent disadvantage in transport

[1] A stock market approach popularized by Humphrey Neill, which holds that in almost any market situation one is safest acting against the prevailing opinion of the moment.

costs and currency exchange rates. Competition drives prices to rock bottom. Recent events drove pine out of the commodity business and back into the specialty business.

Return to specialty status offers many advantages. The scope for competition is narrowed. The potential for favorable pricing is increased. But specialty status demands specialty, not commodity, marketing. It demands flexibility and the capacity to seek out and serve market niches and produce for quality. As we know, the condition of the resource certainly hinders production for quality.

Instead of competing at today's ruinous price levels for 2 x 4's and sheathing boards, quality pine commands impressive prices (Fig. 3). Top pine grades now command higher prices than oak and sugar maple. Yet pine's price is still lower than the premium western species, sugar pine and western white.

Certainly some pine continues to be sold as a commodity and always will--to local builders for rough building. That portion of the production offers little profit potential to new manufacturers. But this market will, of course, help us sell out lower grade, so it performs a valuable service.

The market for pine stumpage reflected overabundance and limited demand for years.

Figure 3.

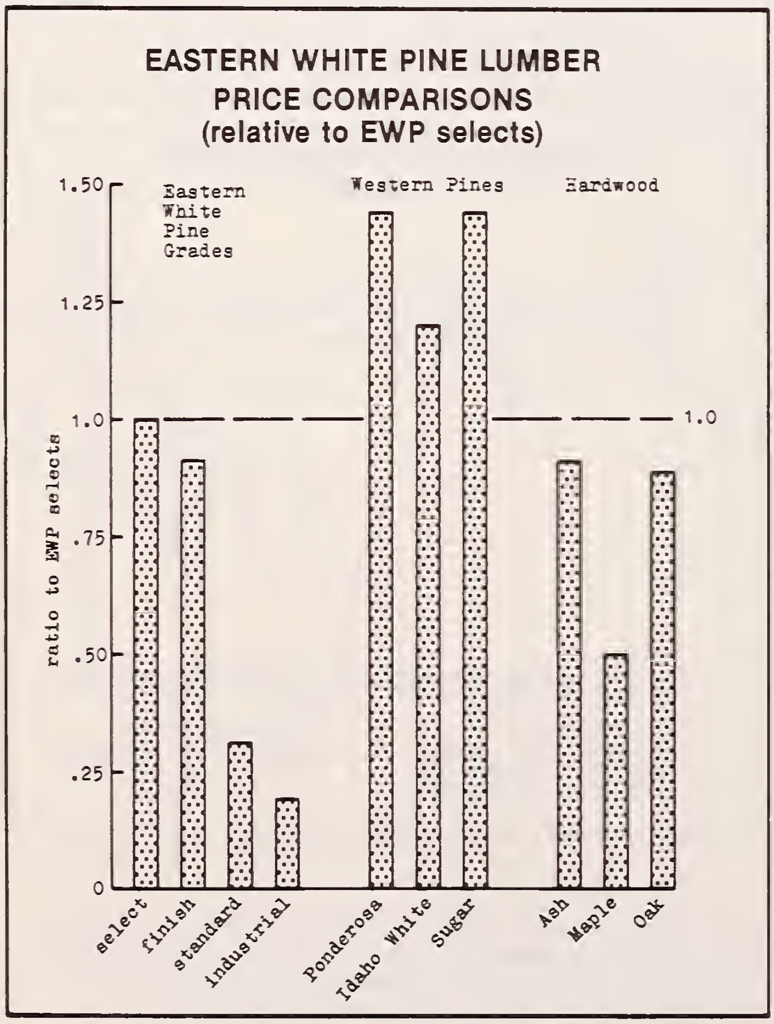
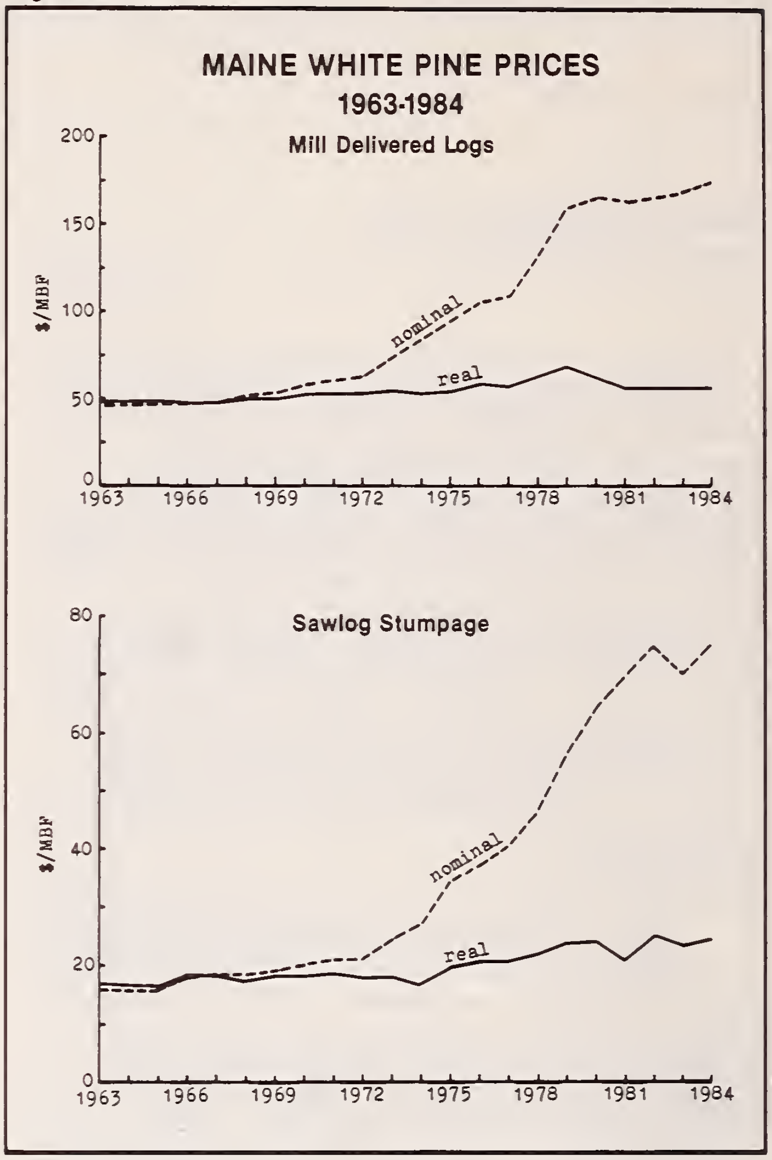


Figure 4.



Only in the early 1970s did real prices begin to turn upward, and then at a rate far slower than the spectacular (temporary) gains seen in the South and West. This pattern was also true for other New England species, suggesting that regional forces were also at work. From 1963 to 1984 in Maine, stumpage rose by 1.9 percent per year real for sawlogs, and by 1.8 percent real for pulp (Fig. 4). There are indications that prices for low grade rose faster than for high grade, which is favorable, since a poor market for low grade has always hindered pine management (Howard, 1985). In New Hampshire from 1961 to 1982, high quality pine logs appreciated by 2.04 percent per year in real terms (Howard, 1983).

This performance can be interpreted as arising from the improved regional competitive position of New England lumber, and from limited supplies of quality logs. At the same time, other markets for low grade have improved. It is certainly not due to scarce overall pine timber inventory, which roughly doubled from 1952 to 1977.

Pine log markets have just begun to recognize quality differences. In the past it was possible to gain a premium by jawboning your log buyers.

Today, log quality is reflected in price lists at more and more mills. Not long ago, I was told that pruning pine was a waste of money because you never got paid for log quality.

What People Do with Their White Pine Stands

A quick look at the resource data suggests vigorous volume growth. Maybe we should worry about supply growing too fast and hurting our price prospects. Following an apparent decline after 1920, sawtimber volume bounced back strongly after 1952 (Table 1), roughly doubling in less than two decades. Much of this was ingrowth.

Table 1.

WHITE PINE AND NORWAY PINE SAWTIMBER VOLUME ESTIMATES 1920-1977

Region	1920	1953	1977
New England	9.8	7.6	14.6
Mid Atlantic	4.0	3.6	5.2
Lake States	8.0	5.0	10.8
Other	1.6	1.1	5.0
TOTAL	23.4	17.3	35.6

Sources: Capper Report, TRR, and Outlook for Timber

In state after state, growing stock and sawtimber volumes have jumped between the most recent surveys. Pine is living up to its reputation and growing like mad. Not only that, it is spreading. Except in Minnesota, its average rose in every state listed. There are many large trees--in 1977 fully one-third of the pine volume was in trees 17 inches and larger.

Because of limited demand and perhaps landowner unwillingness to sell, the pine resource is underutilized (Tables 2,3). For growing stock, Maine's recent growth/cut ratio was 1.6; Minnesota's, 1.9; Michigan's a hefty 3.8; Wisconsin's 2.1. Much of this wood is poor in quality and may not be economically available on the market. But in total raw cords we have pine coming out of our ears.

The important question is, what are landowners doing with this resource? The answer is simple: In general, landowners are standing by and watching their pine go to the dogs.

Look at log quality. In state after state (Table 4), Grade 1 logs are a minuscule portion of the inventory. Looking at Grades 1 and 2 together gives a more comforting picture, but still in all the managers of high grade pine can see that to date the competition isn't onto them yet.

The various state surveys show extensive and increasing overstocking. Markets and landowner disinterest are preventing the maintenance of pine stands at high productivity (low) stocking levels. In Maine, between 1971 and 1982, the area of white pine in fully stocked stands fell by 21 percent--185,000 acres. The area in overstocked stands doubled--up by half a million acres. This is one-fourth of the entire pine acreage.

This is excellent news, because the market could not possibly absorb all of the high grade pine lumber landowners could grow if they set their minds to it. It's not good news for the future pine resource, but it's favorable for managers who have already worked hard to create fast-growing stands of high log quality and intend to continue.

Table 2.

WHITE PINE TYPE AREA AND TOTAL VOLUME TRENDS: CHANGE BETWEEN RECENT SURVEYS

State/Yr		Area of White Pine Type	EWP Vol Growing Stock	Change Sawtimber	EWP Growth-cut Ratio for Growing Stock
MAINE	71-82	+2	+ 17	+26	1.6[1]
NEW YORK	68-80		+ 31	n/a	
MINNESOTA	62-77	-50[2]	+ 1	+19	1.9
MICHIGAN	66-80	+44	+139[2]	n/a	3.8[2]
WISCONSIN	68-83	-20	+ 30	n/a	2

Source: USDA-FS Resource Bulletins

1 based on annual change 1971-81
2 3 northern survey units
3 MN has had a 9% loss of CFL area since 1962

Table 3.

GROWTH REMOVAL RELATIONSHIPS PINES IN THE NORTH 1952-1977

Warning: Do Not Compare Absolute Figures Over Time

	1952[1] Growth	1952[1] Timber Cut	1952[1] Ratio	1977[2] Growth	1977[2] Removals	1977[2] Ratio
Growing Stock MMCF	254	248	102	393	181	217
Sawtimber MMBF	845	929	91	1,333	706	189

Sources: USDA-FS Timber Resource Review, p. 593-595; _______Analysis of the Timber Situation, App. 3

1 data are for white, red, and jackpine.

Note that 1952 data show "Timber Cut", not "Removals"

2 White and red pine. Jackpine not shown separately in these tables.

Table 4.

SAWLOG QUALITY AS RATED BY USDA-FS RECENT SURVEYS BY STATE

State or Region	Percent of Sawtimber in Grade 1	Grade 1 and 2
Southern New England, 1971	3	16
Maine, 1982	12	33
Vermont, 1982	5	n/a
Pennsylvania, 1981	4	17
Michigan, 1980	7	18
Minnesota, 1977	10	23
Wisconsin, 1983	8	n/a

Source RBNE-36, p43, RBNE-81, p35, VT Draft Forestry Plan, p19, RBNE-69, p33, RBNC-72, p52, RBNC-57, p42, J. Spencer, pers. comm.

Silvicultural Economics of White Pine

Why is it that some far-seeing managers have chosen to manage pine stands aggressively? In the face of years of stagnant timber prices, slow markets, and looking out over a generally ragged resource, what considerations motivated these people?

The utility of pine wood, and the excellent prices paid for quality are legendary. The extraordinary growth potential of the species is well known, and is well documented in later papers in this volume. In our area, 4-foot leaders are not so rare as to provoke much excitement. Yields documented for New England show site index 70 yielding more than a cord per acre per year over long rotations (Leak et al., 1970). According to U.S. Forest Service data, 30 percent of the pine acreage can grow 1 cord per acre per year or more.

Pine's growth potential could be its greatest disadvantage. All of us have walked in pine plantations with 15 percent live crown ratios. The species's proclivity for developing unbelievably high levels of basal area per acre is the dark side of its growth potential. It demands culture and thinning over a rotation in order to yield its best rewards.

White pine is not the easiest species to regenerate. Natural regeneration takes a level of care and timing for seed crops that is rare today, and sometimes forbidden by market realities. So, too many pine acres regenerate lower value species when cut, as Thoreau noticed in the 1840's. And in intensively managed stands, an aggressive regime of thinning admits aggressive but less desirable species into understories to outcompete the pine's own progeny and complicate the work in later stand entries.

My previous discussion falls into a common case of blindness--overemphasis on the pine type itself. Much of the pine volume does not occur in the pine type. Old loggers knew that the best and largest pine was often found in mixture with hardwoods on the deep, loamy, well-drained intermediate slopes. When these stands are clearcut, pine is a common volunteer in the regeneration.

Few foresters or scientists are recommending that pine be planted these days, for what seem to me to be generally sound reasons. The ingenious land manager may find instances where these obstacles can be evaded to create rewarding planting successes. But our efforts will be better repaid in managing the 11.5 million acres of pine we have (plus the huge volumes in other types) than in trying to create new acres of a plantation type that is at best cranky to manage.

Successful natural regeneration, as I mentioned, requires attention to timing with seed crops. One of white pine's strongest silvicultural-economic advantages is its ability to keep on earning high rates of value growth for decades. Analyses I've looked at suggest that there is no really clear optimum rotation point in a well-managed stand. There is a broad range of possible rotation ages over which the financial net returns do not vary greatly. No doubt there is room for debate on this as we sharpen our economic analysis on pine.

Managers should take advantage of this fact to plan pine harvests around regeneration requirements. The costs of brush control, or stand replacement by miscellaneous puckerbrush, are high. Certainly high enough to make the typical landowner willing to endure some inconveniences in the interest of successful natural regeneration.

The weak market for small and low grade trees is a major barrier to better management. White pine seems to be avoided as pulpwood. And we won't have enough waferboard plants to solve our oversupply problem any time soon. In local areas, these markets are improving. But the key survival skill for the white pine manager is imagination and enterprise in marketing the thinnings.

The many natural plagues that beset white pine probably account for much of the commonly encountered sense of futility about this species. All I can say about this here is that ways around most of these problems can be found for those willing to exercise patience and care. Some of the later talks on this program discuss these opportunities. But certainly, complacency about these problems is not warranted.

We need careful economic analyses of a wider range of management regimes. Some of these regimes may be more acceptable to small landowners and may be started at lower

investment costs than our treatments aimed at creating pure, fast-growing one-storied stands. Not that I'm against such monocultures at all--I'm just arguing for widening our vision a bit here.

Pine Illusions

We seem to have consciously pushed pine aside in our meetings, our data sources, even our vocabulary. This makes getting information difficult and can discourage the interested newcomer.

Examples:

-- the extremely valuable Demand and Price Situation reports by the USFS do not quote white pine stumpage prices.

-- the national resource summaries usually lump white pine with red pine, and often with jack pine, too, preventing the user from gaining a clear picture of resource conditions and trends.

-- major symposia on forest management in the North ignore or give only token attention to white pine, its conditions and potential.

-- research seems to be driven by an obsession with planting, so that the problems of managing stands get less attention than they deserve.

-- the North has very poor growth and yield information, especially for managed stands. This is a recognized barrier to all intensive forestry, and is no different for pine (see Carmean, 1982, and Bickerstaff and Hostikka, 1977).

-- the view that we shouldn't plant pine, which seems well founded, seems to stretch itself unconsciously into a view that we shouldn't bother to manage white pine.

-- our unwillingness in American forestry to take seriously the management of mixed and multistoried stands creates a very costly blindness in the case of white pine.

-- despite our interest in the long-term future, too often we make today's decisions on the basis of yesterday's markets. Those landowners who were confident in the long-term appreciation potential of quality white pine have been and will be rewarded handsomely.

As D. M. Smith says, white pine should be managed with care or probably not at all. Its culture is an opportunity to restore the practice of the best ideas that we rarely take out of silviculture textbooks. The practice of pine culture at a high level will gain us public respect as craftsmen. This would help counter the image fostered by our critics that we are blind fools struggling with nature to create unnatural forests.

Summary: The Contrarian Case

Pine is a tremendous investment for contrarians who see undervalued situations and have the brains, capital, and patience to profit from them. As the resource data show, these people are few: they need fear little additional competition in the near future. The outlook for the overall pine resource is not good, however, in terms that matter economically. It may grow in area, and will certainly grow in volume. But its quality is poor and not improving.

The possibilities for a range of silvicultural regimes ranging from intensive culture of pure stands to different patterns of mixtures and multistoried stands have hardly been scratched. The potential productivity of pine in pure or mixed stands, and its propensity to seek shade, offer many opportunities. The common fatalism about pine's many natural enemies is, in my view, misplaced. Or is it just an excuse for laziness?

The weakest point in growing pine for quality is the human factor--ourselves. Many people are unwilling to act on what we know about pine. This creates a good outlook for financial success for those few who will.

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THE TROUBLE WITH WHITE PINE

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Reviews the current and historical significance of eastern white pine as an industrial resource. Poses three problems or "troubles" with white pine as a commercial resource: management technology, economic and political concerns, and general acceptability in today's society. Concludes with an action agenda.

Introduction

Eastern white pine (Pinus strobus L.), once the most important softwood lumber species in the Nation, is now one of the least. It doesn't even rate separate billing any longer, but is grouped with red pine for statistical purposes. In 1869, 5.8 billion board feet of eastern white pine lumber were processed (Hair, 1958); that amounted to 62 percent of all softwood lumber produced that year. By 1919, the harvest had dropped to 1.4 billion board feet, which was just 5 percent of total softwood sawtimber output.

The great virgin stands of eastern white pine were gone. We had mined that resource into virtual extinction, and gone on to expliot the forests of the South and West. Of course, we got something in return. Loggers and mill workers earned a living, some cutovers became productive farms, mill owners sometimes got rich, and many villages and farmsteads were built from the lumber.

In my own state of Michigan, more than 100 billion board feet of white pine were cut between 1849 and 1909 (Steer, 1938). Today Michigan's total inventory of white pine is just 2.6 billion board feet (Raile and Smith, 1983), less than one year's harvest in the 1870's or 1880's! Annual removals now run no more than 25 million board feet, about one-half of net growth.

And so it is at the national level as well. Red and eastern white pine together comprise only 1.6 percent of all softwood sawtimber removals. And removals are only one-half of growth (USDA Forest Service, 1982). So what's the problem? We grow more white pine than we use, and inventories are increasing. Why try to grow more? We have more than we need already. And even if we didn't, it wouldn't make that much difference. A tiny increase in output from the South, or the West, or from Canada, would make up any shortage. In fact, we could do without eastern white pine entirely as a commercial resource and never notice it.

Still, there are forestland owners with white pine to manage and sell, and there are loggers and mill workers and owners who make at least a part of their livings from processing white pine. For these persons, eastern white pine can have real importance, and opportunities for better management and utilization can help.

But anyone who seeks to foster a significant expansion in eastern white pine supply and utilization faces some serious problems. To my mind, these "troubles" fall into three groups: technological, economic, and social.

Technological Troubles

The silvicultural guides for eastern white pine (Burns, 1983; Lancaster and Leak, 1978) say that although it occurs in pure stands, most of it grows in mixture with many other eastern species. I wonder how it got there--all that old growth white pine we used to have? Much of it was in pure stands, from what I can gather. Obviously, we don't know all we need to know about the natural regeneration of this species.

One way of managing white pine it to try to reproduce existing pure stands and to favor the white pine that occurs in other types when no more valuable species is in competition. This is what most owners do, if they manage at all. But white pine can also be planted.

We have a lot of experience with white pine as a plantation species. In the North, white pine was widely planted during the 1930's. Most plantations received no subsequent care and many of them were lost to hardwood competition, blister rust, and the white pine weevil. The species has such a bad name that foresters avoid using it for reforestation. Only 58,000 white pine seedlings were planted in Michigan in 1981 for reforestation purposes, while over 10 million red pine and jack pine seedlings were planted (Levenson and Hanover, 1985).

In the southern part of its range, where blister rust and weevil problems often are less severe, eastern white pine has greater promise. In the North we probably are going to have to wait for the development of strains of eastern white pine that have genetic resistance to the rust and to weeviling. The prevention or control of weevil injury is critical because two or more injuries in the butt log make the tree grade 3 or 4, and this means that more than one-half of the volume will be number 4 or 5 common lumber, often an essentially unsaleable commodity (Brisbin and Sonderman, 1971).

Because of blister rust and the white pine weevil, eastern white pine is a chancy species to manage. Some stands develop beautifully with little or no loss or damage, while others are heavily attacked. We can make better use of blister rust incidence zones in selecting plantation sites, and we can use chemicals to control the weevil, but white pine still carries more risk than other more trouble-free species. But how does it look from the economic point of view?

Economic Troubles

Let's look at the economics of making white pine plantations, and let's assume that we will not have any significant pest problems. A fully stocked 70-year-old plantation of eastern white pine in the Lake States will yield about 45 Mbf per acre on site index 60 land (Marty, 1965). With a stumpage price of $65 per Mbf and selling costs of 10 percent of gross, the net stumpage value of this stand at harvest would be $2,633 per acre. Using a 4-percent discount rate, the present value of this harvest is $169 per acre.

If the plantation can be established, released, and protected, and if land costs, real estate taxes, income taxes, and administration expenses all together amount to $169 per acre, then the investment will earn exactly 4 percent. If costs are lower, the rate of return will be greater than 4 percent, and if costs are higher the return rate will be less. Cost data for the Lake States (Winebar and Gunter, 1984) indicate that site preparation and planting alone would cost $180 per acre in average conditions. Obviously, white pine plantations in the Lake States, and indeed in the North as a whole, do not appear to be very good investment opportunities at present.

But how about white pine in the more southern part of its range? Here the prospects are better. An 8-by-8-foot plantation, on land with a 25-year site index of 60, will yield 17 Mbf per acre at age 30. Using the same price assumptions, this plantation would be worth $995 per acre at harvest and would have a present value of $306 per acre. Economically, this is a more viable situation.

In the more southern part of its range, then, there are many opportunities for eastern white pine plantation projects, while in the North relatively few plantations will prove to be even modestly profitable. We need a cheaper plantatiion technology before it will be profitable to expand planting programs in the North.

Social Problems

More and more I find myself agreeing with Aldo Leopold (1933), who wrote "The conservation movement is, at its very least, an assertion that ...interactions between man and land are too important to be left to chance, even that sacred variety of chance known as economic law." So, if we want to expand eastern white pine production, and private capital is not available to do the job, we must turn elsewhere. And of course, that "elsewhere" is to government.

A major social problem in forestry stems from the ups and downs in economic and political affairs. Some years forestry investments look good because of lower than usual interest rates and good price/cost ratios. In other years they look very bad. In some administrations forestry programs are favored and ample public funds are available. In other administrations budgets are tight and forestry is a back burner concern. So sometimes we have the resources to manage well, and sometimes we don't. And in timber growing we can lose 50 years of production with just a few years of neglect.

Another kind of social problem stems from attitudes. A good many Americans do not consider timber harvesting socially desirable. In their minds it is synonymous with the destruction of the environment. They feel the same way about using chemicals to control competing vegetation and pests. We may know that these people are wrong, but that doesn't matter. They do hold these beliefs, and that means that timber programs draw fire.

Then too, white pine happens to be a beautiful tree. Its distinctive growth form makes it an easily recognized component of many eastern forest types. It is arguable that the species has more value as scenery than as lumber. I'm sure any large-scale increase in utilization that resulted in an appreciable decline in this valued landscape component would be bitterly resented by many.

An Agenda

First, let's find out if there is a shortage of eastern white pine. I have found that removals exceed growth for some species in some survey units in Michigan, even though growth is three times removals for the state as a whole. We can argue for expanded programs where net growth exceeds removals and inventories of stumpage available for harvest are falling or will fall.

Second, let's do all we can to improve our technology for growing eastern white pine. We need cheaper ways of making plantations, we need genetically improved planting stock, we need better information on the incidence of blister rust so that we can identify low-risk areas with more assurance, and we need cheap, safe, and effective methods of controlling weevils.

Third, let's learn to work with concerned groups to identify ways for resolving conflicts between timber production and other forest uses and values. We need to demonstrate that timber growing and timber harvesting are compatible with other uses, and indeed indispensable to some. There is some public education to be done, but more than that, we must be willing to compromise in order to gain public trust.

Finally, let's work with legislators to help them to see the importance of a reasonable degree of continuity for public forestry programs. The white pine resource, along with all other forestland ecosystems, will benefit.

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THE LORE AND LURE OF EASTERN WHITE PINE

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Eastern White Pine (Pinus strobus L.) will continue to be used for finish work, upkeep and furniture. Shipping related demands will be tied to the general economy; the trend toward pallets will continue. Wood energy demands allow increased utilization of low quality pine. Stumpage demand will remain strong for higher grades. Total market will be driven by products made from lower grades.

"At the Parliament Begun and Holden at Westminster, the Twenty fifth Day of November, Anno Dom. 1710. In the Ninth Year of the Reign of our Sovereign Lady ANNE, by the Grace of God, of Great Britain, France, and Ireland, Queen, Defender of the Faith, and being the First Session of this present Parliament.

An Act for the Preservation of White and other Pine-Trees growing in Her Majesties Colonies........in America, for the Masting (of) Her Majesties Navy" (Chronica Botanica 1949).

That 1710 act was the policy action taken by the Parliament to meet the demands of its navy for masts. From the first days of settlement in the early 1600's to the turn of the twentieth century, eastern white pine (Pinus strobus L.) was the species on which the United States was built. White pine was important to society because it was a resource; a means to an end. It provided goods and services which consumers of the times demanded. Although white pine has lost its national position to western and southern pine species, it is still a major softwood species in the Northeast, Lake States, and parts of eastern Canada.

My purpose today is to discuss the demand outlook for eastern white pine. What do we use it for? What does the future hold? What is the lure, with a "u", of eastern white pine? And, because the past is prologue, I will set the stage with demand-side lore, spelled with an "o".

The Lore of Eastern White Pine

The folklore associated with eastern white pine could, in itself, be the topic of an entire, entertaining symposium. For example, Peattie (1950) wrote that the pinery was so extensive that in the late spring, storms of yellow pollen were blown onto decks of ships at sea so that some sailors thought it was "raining brimstone". I will only highlight some major stories and add a few tidbits which I uncovered while reviewing the literature. I am endebted to Alimi and Barrett (1976) who reviewed some of the important historical literature.

Since colonial times, eastern white pine has been the most important conifer in the Northeast and Lake States. It, more than any other tree, built the United States (Peattie 1950). In 1609, the first shipment of masts was made to England. The New World lumber industry started with the establishment of a sawmill in York, Maine, in 1623. A second mill was built in South Berwick, Maine in 1634. By 1675, there were fifty sawmills in the region (Carroll 1973). Regular traffic in ship masts began in 1645.

In 1691, the British took the first steps to protect mast trees for their navy by claiming all non-private white pine, twenty-four or more inches in diameter, as measured twelve inches above the ground, to be reserved for their navy. Supporting policies were enacted in 1710, 1729 and 1761. The practice of marking these trees with a broad arrow or "R" for "Royal" was instituted around 1719 (Harlow 1957). Evidence of such marking on some old trees in Maine was documented as recently as 1935 (Lownes 1935). From 1740 to 1770, Portsmouth, New Hampshire, only eight miles east of today's symposium, was the center of the white pine lumber and mast trade. The colony of Massachusetts Bay minted a "Pine Tree Shilling" during the 1700's (Pike 1967).

The role of eastern white pine in the American Revolution is perhaps not fully appreciated (Peattie 1950). That the Broad Arrow Policy led to friction between the colonials and the crown's agents is well known. At least one agent was tarred and feathered here in southern New Hampshire. In 1769, a Vermonter was fined 800 pounds sterling for cutting sixteen potential mast trees.

But, Yankee ingenuity probably got its start under the Broad Arrow Policy. Because it was illegal to cut non-privately owned white pine greater than 24 inches, the colonists regularly sawed their boards no wider than 23 inches to avoid creating evidence for prosecutors. And, in an early expression of what has been a long standing method of administering justice in the woods here in the north (as well as in other regions of the country), unknown parties set fire to 50 square miles of Maine to protest the policy (Pike 1967).

During the Revolution, 300 patriots banded together and moved mast trees away from the Maine coast to make supply and repair of the British fleet more difficult, thus contributing to the eventual defeat of the Crown (Albion 1926; Peattie 1950). The white pine tree was also a symbol of the Revolution. At Bunker Hill, a white pine was in the corner of the flag flown by the colonials, and the revolutionary navy had a green pine tree on a field of white as its early flag (Pike 1967).

On the strength of its white pine resource,

New England led the nation in lumber production until 1840. The species was used for construction, cooperage and ship building. Large quantities were shipped to the mid-Atlantic states and to Europe. The market was for high quality pine which was only available from old growth. Orders frequently specified that planks be free of knots, fifteen to thirty-six inches wide and twenty-five to thirty feet long. New York and Pennsylvania took command only briefly as national expansion and the development of the railroad helped deplete the old growth in these states and shift the production lead to the Lake States (Jenson, Behre, and Benson 1940).

White pine lumbering came to the Lake States in the 1830's. Large scale operations began along Wisconsin's rivers around 1850. By 1875, the white pine resource had vanished. Mills closed, moved west, or shifted their input demand to hemlock or hardwoods (Raney 1935).

From 1840 to 1860, special rafts of great mast timbers were floated down the Susquehana River in Pennsylvania. These timbers were up to ninety feet long and forty inches in diameter and were lashed together with hickory withes. The rafts themselves were steered with oars, fore and aft, through the river's rapids (Tonkin 1940).

Prior to 1889, eastern white pine supplied at least half of the nation's softwood requirements. With the depletion of the old growth, market share declined rapidly to as low as two percent of softwood lumber production in the 1930's before recovering to the five percent level in the 1940's (Fedkiw and Stout 1959).

When the high quality old growth was gone, the lumber industry turned to the vast acreages of second growth pine which had established itself on the many farms abandoned in the Northeast after the Civil War. Lumber was cut for box boards and specialty products requiring only short clear pieces such as cooperage and matches (Jensen, Behre and Benson 1940). In 1913, 900 million board feet of lumber, one-third of the total production, was utilized to meet the demand for wooden boxes. Boxes were the most important end product for twenty-five years. At one time, box demand required eighty percent of the white pine output. Sixty-three percent of New Hampshire's 1925 production served as inputs into box production. The demand for white pine fluctuated with changes in the box and crate market rather than with the general softwood lumber market (Fedkiw and Stout 1959).

To promote the use of white pine, The White Pine Bureau was established in St. Paul, Minnesota in the early twentieth century. It published a series of monographs on the architectural use of pine (Wilson and Hough 1966).

White pine met consumer demand for products other than timber, as well. Old stumps and roots were set on their sides at field edges to serve as long lasting fences. The inner bark in May and June is good to chew and Old-time New Englanders used to make candy strips with it. An early English writer claimed " the distillled water of green cones taketh away wrinkles in the face, being laid on with cloths" (Harlow 1957).

Eastern white pine was not strictly a U.S. species. It has been in demand in Canada for many of the same uses as on this side of the border and the development of its industry follows that of the U.S. experience. The Canada Lumberman did published a series of special issues from 1934 to 1943 promoting new uses and markets for white pine.

The fame of Pinus strobus has spread beyond North America. True, white pine products were exported to Europe and the Caribbean. But the tree itself has also been widely introduced. Captain George Weymouth brought white pine seeds to England in 1605 (Peattie 1950) and Lord Weymouth is credited with introducing the species to Europe in the very early 1700's (Harlow and Harrar 1968). However, one source (Garden and Forest 1890) presents evidence that an eastern white pine was planted at Fontainbleau, in France in 1553, pre-dating Lord Weymouth by 150 years and Captain Weymouth by fifty! From the 1700's to the 1900's, so-called Weymouth pines were planted all over Europe: England, Germany, Switzerland, Italy, France, central Europe and the Soviet Union. It has also been planted in Japan (Wilson and Hough 1966).

Finally, it should be noted that the wanton exploitation and catastrophic fires associated with white pine logging in the late 1800's played a major role in galvanizing public opinion in support of conservation (Peattie 1950). In the spirit of Pinchot's conservation movement, an early forester, Carl A. Scheneck, planted white pine at the Biltmore Estate near Asheville, North Carolina in 1899. This plantation, which exists today, was used by Frothingham in his 1916 thinning experiments (SEFES 1971).

The Lure of Eastern White Pine

Consumers do not want eastern white pine timber per se, but they do want the goods and services of products made from that timber.

> "Because of a unique combination of properties- its moderate strength, straight grain, soft and uniform texture, stability and ease of drying and resistance to decay- the eastern white pine is still regarded as the most intrinsically useful of all American softwoods" (Lockard 1960).

Whatever changes occur in the demand for eastern white pine timber depend directly on changes in demand for its many end products. Today, the primary white pine end products demanded by consumers are yard lumber and wooden household furniture (Putnam 1978).

Because the demand for eastern white pine is derived from end product demand, it is important to look not only at end product demand but also at the fundamental forces which determine that

demand. Such forces include growth in population, economic activity and income.

U.S. population is expected to increase by approximately one-third by 2030. How that population is sheltered influences forest products demand and, through the mechanism of derived demand, the demand for timber. Prior to the recent recession, forecasts for average annual new housing starts during the 1980's and 1990's were estimated at 2.6 and 2.2 million, respectively. Current estimates for the rest of the '80's have been revised downward to an average of 2.4 million starts per year. These estimates are for all housing: single family, multi-family and mobile homes. Over 1.7 million units were started in 1984, and recent estimates put 1985 activity at over 1.9 million. Annual housing start estimates for the 1990's and beyond have also been revised downward from prior forecasts but they are still projected to be at least 2.0 million units.

Although these forecasts suggest smaller than expected increases in demand, other housing factors will also affect timber use. For example, 87 percent of new housing units constructed in the 1980's and 90's will be conventional single and multi-family dwellings and the average number of square feet per unit will increase. However, the use of wood per square foot will decline ten percent by 2030. A surge in housing starts in the late 1980's is expected to relieve some of the pent-up demand resulting from recent low levels of housing construction (USDA, FS 1982).

Forecasts of Gross National Product, one measure of economic activity, call for growth in GNP of 3.7 percent annually through 1990, as measured in 1972 dollars. Beyond 1990, the annual growth rate is expected to decline slowly to the two percent level. Real growth rates are correlated with increasing demands for forest products.

There is also a strong positive correlation between per capita disposable income and the consumption of forest products. With few exceptions, per capita disposable income has grown more than 3.0 percent annually since 1950, as measured in 1972 dollars. Expectations are for continued increases through 2030 of between 1.8 and 2.8 percent yearly.

In summary, the trends in macroeconomic indicators point to increased demand for end products. There are differences, however, in demand trends for the classes of end products and the timber used to create these end products. White pine end products and timber is no exception.

Why should foresters and scientists interested in eastern white pine be concerned with population growth and related shelter requirements, GNP and per capita income? White pine is rarely used as structural lumber in construction. But projections for new housing starts, replacements, and housing upkeep and maintenance are important because white pine is demanded for siding and for decorative trim, cabinets, panelling and other residential interior uses. During slack periods for housing construction, upkeep and maintenance become especially important. Retail lumber yards, a major final sale point for eastern white pine, do a brisk business providing lumber to the homeowner for upkeep and maintenance.

Moreover, people need furniture to put into these houses; wooden furniture is a chief outlet for white pine. Furniture demand is related to housing demand and the economic well-being of the population.

Finally, shipping has been an historic demand sector for eastern white pine. While demand for wooden boxes is now a pale shadow of historic levels, low grades of pine are being used increasingly in pallet manufacture. Pallet demand is driven by the overall strength of the economy.

The Demand for White Pine Lumber

There are speakers and participants here who are better acquainted with the details of pine markets than I, so I will limit myself to a macro-long-term view of trends in end product markets and their implications for white pine lumber and stumpage markets.

Lumber for Residential Uses

Eastern white pine is no longer a commodity grade material and is rarely used in residential housing construction. But, even as a specialty wood, demand for its lumber is linked to housing demand. Last Saturday, I took a trip to a local retail lumber yard and found white pine for shelving, bookcases, trim, paneling, furniture making, decorative barn boards and a host of other advertized special uses for the home. One of our later speakers will be please to hear that most of the pine on the display came from his company's mill.

Trends in new housing will be a crucial factor in white pine lumber demand. As described earlier, revised projections still anticipate at least 2.0 million housing units per year far into the future. Key determinants of housing demand are household formations, vacancies, housing stock replacements and conversion of non-residential structures to housing units. Although household formation should average 1.5 million households for the 1980's, a steady decrease is expected thereafter to the 600,000 level by 2030. Replacements of older housing units will become an increasingly important component of new housing demand (USDA, FS 1982). White pine lumber will be one input for molding, trim, cabinets and other interior work as well as for siding and shingles in new housing.

Demand for white pine yard lumber is also derived from the housing upkeep and maintenance sector. When new housing starts fall off during economic hard times, lumber demand is buoyed by shifts to upkeep and maintenance. People who can

not afford to move to new quarters renovate their existing homes.

The national history of lumber consumption for residential upkeep and maintenance shows a greater than 3.0 percent average annual increase from 1970 to 1976. Absolute annual volume consumption increases, but at a decreasing rate. Consumption is expected to grow by more than 1.6 percent from 1976 to 1990, and by about 1.0 percent thereafter (USDA, FS 1982). Board is expected to be heavily substituted for lumber, in general, but not for the kinds of final uses to which white pine is put.

The producer price indices relevant to eastern white pine in the residential housing sector are both end product and species specific. The millwork price index, is not species specific, but its performance probably reflects that of white pine in this end use. For the period 1963 to 1984, the index advanced at an average annual rate of 6.0 percent (Table 1). That is essentially the same performance as the Consumer Price Index.

Table 1. Rates of Price Index Growth for End Products Utilizing Eastern White Pine.

RATES	EWP#3C[b] 1963-80	MILLWORK 1963-84	BOXES 1966-84	FURNITURE 1971-84
Nominal	0.0731	0.0596	0.0561	0.0618
Real[a]	0.0124	0.0011	-0.0086	-0.0170

[a]Relative to the Consumer Price Index.
[b]Eastern White Pine, #3 Common.
Source: U.S.D.L., Bureau of Labor Statistics.

The Bureau of Labor Statistics began to compile a producer price index for pine molding in 1983. It is too soon to discern any trends.

The price index for eastern white pine number three common experienced a 7.3 percent average annual nominal increase from 1963 to 1980 (Table 1). Relative to the CPI for the same time interval, this represents about a 1.2 percent average annual price increase. For the period 1972 to 1980, nominal prices grew 11.5 percent annually. When adjusted for general inflation as measured by the CPI, number three common grew 2.5 percent annually, in real terms. That this grade of lumber outperforms inflation is not a recent phenomenon. Fedkiw and Stout (1960) found that number three common prices grew faster than inflation for the period 1937 to 1959.

Lumber Related to Manufacturing

Furniture manufacturing may be the largest sector of demand for white pine, at least in terms of physical volume (Putnam 1978). Number Three Common has been the nearly exclusive input in rustic furniture manufacture (Wallace and Amidon 1958). Nationally, annual lumber consumption of all species for wooden household furniture rose from 2 to 3 billion board feet from 1948 to 1970. In the early 1970's, furniture styles permitted plastics to replace wood, so total lumber consumption dipped to 2.5 billion board feet per year. Wood is expected to remain in demand for furniture because of the ease of finishing and repair, but more importantly, because many consumers have a "deep-seated preference for wood furniture" (USDA, FS 1982).

The performance of the producer price index for wooden household furniture from 1971 to 1984 provides empirical evidence that consumers were moving away from wood furniture manufactured from white pine and other species. The index grew at an average annual nominal rate of 6.2 percent, which, when adjusted for the relative changes in consumer prices, represents a 1.7 percent average annual decrease (Table 1).

While furniture constitutes the largest manufactured end product use of eastern white pine, the species is also in demand for a host of other manufactured products. It is and has been used for wooden wire reels, shoe heels and patterns, matches, fence posts and industrial molds (Putnam 1978; NELMA 1950). Number 4 and 5 Common have been used in the production of finger-jointed, edge-glued panels from re-manufactured full sized lumber, eliminating rot, shake, wane and knotholes. Careful cutting of low grade pine yields clear, defect-free wood for the manufacture of toys, novelties and millwork (Petro and Lamb 1968).

Total lumber demand for all manufacturing, which includes commercial furniture, other manufactured goods as well as household furniture, is expected to expand from 5.5 billion board feet in 1990 to 7.9 billion board feet in 2030 (USDA, FS 1982). Other input products such as reinforced plastic, fiberglass, metal, fiberboard and reconstituted wood panels will continue to make inroads on lumber's share of the manufacturing market. Future demand for eastern white pine lumber should continue to keep pace with overall demand for lumber inputs for manufactured products. Technological advances to reclaim more clear lumber will help the market for lower grades of pine.

Lumber in Shipping

The wooden container industry has been declining since the 1920's. For example, in 1925, 58 New Hampshire box firms used over 60 milion board feet of white pine. By 1966, the number of firms had dwindled to 11 and they were using less than 30 million board feet of all species (Wallace and Penick 1966). Nationally, lumber use in wood containers dropped 70 percent from 1948 (3.997 billion board feet) to 1976 (1.140 billion board feet) (USDA, FS 1982). The continuing decline is reflected in the producer price index for wooden boxes. From 1966 to 1984, the index fell in real terms nearly one percent annually.

Consumption of lumber of all species used in making wood containers will continue declining. Other products, such as plastics, paperboard and multi-walled bags, are low cost substitutes which lend themselves to automation and incur lower freight costs because of lower weight (USDA, FS 1982). Logic dictates that low quality white pine lumber will find only smaller and smaller future demand in the box industry.

Although wooden boxes are becoming a vestigial industry, low quality white pine lumber is still in demand for pallet construction. Total annual pallet production in the United States has risen from 62 million in 1960 to 196 million in 1976. Expectations are for growth in annual production to 605 million pallets by 2030. Lumber requirements to make these pallets will nearly triple from 1976 to 2030 (USDA, FS 1982). This end product demand is driven by the need for better materials handling. Low quality white pine which formerly went to boxes may be able to claim a substantial share of this input market. It will, of course, have to compete with abundant low grade hardwood, and be subject to the business cycle which governs the demand for pallets.

There is a limited and slow growing market for lumber for dunnage, blocking and bracing. As with pallets, eastern white pine has no special species advantage here. I am reminded, however, of a request I once tried to fill in Maine for a limited number of large white pine trees to be manufactured into blocking for shipbuilding at the famous Bath Iron Works.

Implications for Timber Demand

Just as the demand for white pine lumber is derived from the demand for the end products which use that lumber as a production input, the demand for white pine sawlog stumpage is derived from the demand for white pine lumber. We have seen that because future demands for housing are expected to grow, we can expect demand growth for those grades of lumber which serve that sector. With the exception of wooden furniture which is strongly linked to housing activity, future demand for lumber for manufacturing will not be as important. The future strength of lumber in shipping will depend on how well white pine is utilized in pallet making. As has been the case in the past, the overall market for white pine lumber will depend on the strength of the market for abundant low grades of lumber.

Price performance of sawlog stumpage show that white pine has remained in demand in New Hampshire and Maine over the period 1963 to 1984. Nominal New Hampshire sawlog prices advanced 8.7 percent annually. This represents nearly a 2.0 percent real annual increase. In Maine, annual price growth was 7.6 and 1.9 percent on a nominal and real basis, respectively. The other important softwoods, hemlock, spruce and fir, experienced either a real decline or showed no significant advance over general inflation.

Pine sawlog stumpage prices should continue to mark real gains over the long term. White pine has earned a place as a specialty wood which will allow high quality pine to command better than average prices. Lower quality pine, if end product demand calls for it, will also do well, especially on a percentage basis. An additional dollar on a low price is a greater percentage increase than another dollar on a high price.

Paper and Board and Wood Energy

Paper and board consumption has generally increased both on a total and per capita basis for the last fifty years (USDA, FS 1982). Rising per capita incomes and growth in the domestic and world economies are expected to fuel continuing increases in total and per capita paper and board consumption.

White pine, however, has not been very important to the paper and board sector. In the Northeast and Lake States. through the 1970's and early 1980's, pine has provided twenty percent or less of the softwood roundwood and ten percent or less of total roundwood requirements. Some individual mills do use white pine as a significant part of their furnish. In fact, later in this symposium you will hear from one corporation that plans to be highly dependent on white pine for its fiber supply.

In New England, white pine fiber is not in much demand at pulp and paper facilities. In New Hampshire, less than three percent of pulpwood volume is eastern white pine; in Vermont and Maine, the species constitutes five percent or less of mill requirements. Pulpwood price trends indicate the lack of demand in these states. New Hampshire real stumpage prices declined from 1963 until 1978. They have increased in real terms only slightly since then. From 1973 to 1984, Maine white pine real stumpage prices essentially did not grow. The slight upturn in prices now in evidence is driven by the demand for wood energy rather than the demand for pine as pulpwood.

The use of wood for the production of energy has experienced a revival since the OPEC oil embargo in 1973. Demand for wood-based energy is strongly influenced by the price of substitutes, primarily oil.

Forest industry traditionally either dumped or burned its wood waste. In recent years, industry has moved to utilize wood waste to supplement and replace other energy sources. In the last five years, the industry has made major committments to using wood fiber for energy for its own purposes and for sale to public utilities. Energy is no longer generated strictly from waste material. Timber is now harvested specifically for energy production.

As a result of this new demand and the development of biomass harvesting equipment, substantial volumes of eastern white pine are finding markets. Every forester here has probably seen dozens of white pine stands which, due to weevil damage, lack of management and other

factors have little future as even low-grade sawlogs. Pulpwood markets have not been strong, so the advent of the energy market will allow many of these stands to be profitably liquidated. The energy market is not unlimited, but the potential to expand white pine fiber markets exists.

Other Uses

Eastern white pine has also been in demand for non-timber uses as well. Although not very popular in Northern New England, white pine is used extensively as a Christmas tree. Moreover, it is widely planted in our suburban neighborhoods as decorative shrub and ornamental tree.

Summary

Macro factors indicate an upward trend in demand for important end products using higher grades of white pine lumber. While other end products are also expected to be in increasing demand, the low grade lumber and fiber used in their manufacture will be competing with abundant substitute materials. From a demand perspective, managing for grade in the forest and at the mill appears to be most promising. Aggressive marketing and technological innovation are needed to deal with the all-too-abundant low quality component of the inventory.

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EASTERN WHITE PINE: INVENTORY AND DYNAMICS

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Timberland in the eastern U.S. contains 4.5 million acres of white pine forest type, but most of this resource is found in New England and New York. Here, the eastern white pine growing-stock resource is growing at nearly twice its removal rate. The sawtimber resource is composed primarily of lower tree-grade material, which has shown some improvement in quality during recent years.

Background

Statewide forest inventories are part of a national program, initiated when Congress passed the McSweeny-McNary Act in 1928. At that time, woodland managers and those involved with forestland policy experienced a growing fear -- fear that our nation's forest resources were being used faster than they were growing. A special research group of the USDA Forest Service (today known as Forest Inventory and Analysis), was formed to address the problem prompting these fears. Their task: to conduct periodic inventories designed to determine the supply, growth, and use of forest resources in each state.

These same forest inventories have been conducted periodically over the years, but the fear of a depleting resource base did not diminish. Increased stress on the forest resource from uses such as recreation and wildlife, coupled with the threat from environmental impacts such as the white pine weevil that damages eastern white pine (Fig. 1), caused concern by many woodland managers that the timber resource was being depleted.

As a result, the Forest and Rangeland Renewable Resources Planning Act was passed by Congress in 1974. Commonly known as RPA, this Act broadened the scope of earlier legislation to include (1) more multi-resource assessments, (2) inventories of both the forests and the rangelands of the nation, and (3) periodic national updates.

The thrust of past and current legislation has been to improve the periodic national assessments. The requirement of national information means that data collected in each state must be additive. Thus, the inventory is directed by a set of national specifications, definitions, and accuracy requirements.

Figure 1.--Infestations of the white pine weevil cause excessive branching and a reduction in tree quality, as has occurred in this white pine located in Waldo County, Maine.

The Forest Inventory and Analysis program was also designed to meet as many local and state information needs as possible. Analyses of each state's timber resource and other, special analyses are needed to answer specific questions about the resource base. Our analysis of the eastern white pine resource is one example of a special analysis.

We have tailored our analysis of eastern white pine to answer the following questions: what is the inventory supply of the eastern white pine resource, and how has it changed? To answer these questions, we compiled data from previous and current inventories for several states[1]. We will begin by discussing the eastern white pine resource in the eastern United States, and then focus on the inventory and dynamics of this particular species in New England and New York.

[1]/The resource statistics used in this paper were taken from various published and unpublished Forest Service resource bulletins. For specific references, or more information, contact the authors.

Extent of the White Pine Resource

We will limit our discussion of the eastern white pine resource to the United States, even though the species ranges throughout most of eastern Canada as well. In the United States, eastern white pine grows from New England west to the Lake States, and south to the Appalachian Mountains of North Carolina and Tennessee.

Soil and climatic conditions primarily influence the growth of eastern white pine. Areas of deep, glacially deposited sands or gravels, coupled with a cool climate, are ideal site conditions because they limit competition from hardwoods.

Economic conditions have also affected the development of eastern white pine stands. The species is an avid pioneer on abandoned farmland, especially cropland. Plowing and other farm treatments to the soil eliminate hardwood rootstock. With little competition from hardwoods, eastern white pine is favored (Oliver 1981). In the eastern United States, much of the land originally cleared for farms during the 1700's and 1800's has reverted to woodland over the ensuing years. This has resulted in some stands of eastern white pine where seed sources were available.

How much eastern white pine is there on timberland in the eastern United States, in both area and volume?

Timberland Area

Timberland area is usually reported by forest type. According to USDA Forest Service definition, forest type is a classification of forest land by the species (eastern white pine in this case) that forms a plurality of live-tree basal-area stocking. Even though eastern white pine frequently occurs in pure stands, it is an important component of many different forest types (Wendel 1980). In New England, eastern white pine is commonly found in mixed stands, occurring frequently in oak-hickory forest types.

For our area analysis, we were restricted to dealing only with the eastern white pine forest type. Thus our area statistics will be conservative. Even so, we identified seventeen states that contain significant acreages of the eastern white pine forest type (Table 1). Other states contained white pine forest type, but in very small acreages.

Timberlands in the 17-state area contain approximately 4.5 million acres of the white pine forest type. Timberlands in Maine account for the largest area of eastern white pine forest type, approximately 1 million acres. Maine, New Hampshire, and New York account for approximately 2.5 million acres of eastern white pine type, or 56 percent of the total 17-state area.

Table 1.--Area of eastern white pine forest type and volume of eastern white pine in selected Eastern states

State	Timberland area	Growing-stock volume	Sawtimber volume
	Thousand acres	Million ft^3	Million fbm
Connecticut	60	115	357
Maine	1,031	1,736	6,520
Maryland	25	33	23
Massachusetts	401	877	2,624
Michigan	214	544	2,607
Minnesota	66	195	1,068
New Hampshire	812	1,529	5,210
New York	670	1,178	3,893
North Carolina	143	422	1,762
Ohio	125	57	151
Pennsylvania	224	494	1,235
Rhode Island	23	49	145
Tennessee	11	183	827
Vermont	324	449	1,404
Virginia	152	360	1,365
West Virginia	38	126	329
Wisconsin	178	413	1,945
All states	4,497	8,760	31,465

Growing-stock Volume

Net growing-stock volume (expressed in cubic feet) is an estimate of the amount of wood in trees suitable for industrial forest products. It is the net volume in live, predominantly sound trees greater than 5.0 inches d.b.h. (diameter at breast height), between a 1-foot stump height and a 4-inch top d.o.b. (diameter outside bark), or to the point where the main stem breaks into branches, if that is before it reaches this top diameter.

Timberlands in the 17-state area contain approximately 8.8 billion cubic feet of eastern white pine growing stock (Table 1). This is an estimate of the growing-stock volume in all eastern white pine trees found on timberland in the region, regardless of the forest type in which the trees occurred. Again, timberlands in Maine, New Hampshire, and New York dominate, with 51 percent of the total.

Some states have greater volumes of eastern white pine growing stock associated with lesser areas in the white pine type. Volumes per acre differ from one state to another for a variety of reasons. First, certain areas of timberland contain eastern white pine in less than pure stands. Second, the size of timber in eastern white pine stands may differ because of their harvesting and land use histories. And finally, certain areas have site conditions better suited for eastern white pine, resulting in higher volumes per acre.

In states bordering the southern range of eastern white pine, volumes per acre tend to be highest. A study in the Southern Appalachians showed that eastern white pine had better growth rates than any species except yellow-poplar (Doolittle 1958). However, white pine may have better growth rates than its associated species on timberlands throughout the Eastern United States.

Sawtimber Volume

Net sawtimber volume (expressed in board feet) is the volume in live, predominantly sound trees, and differs between softwoods and hardwoods. For eastern white pine, it is the volume in trees greater than 9.0 inches d.b.h., between a 1-foot stump height and a 7-inch top d.o.b., or to the point where the main stem breaks into branches, if that is before it reaches this top diameter.

Sawtimber volume is probably the most important statistic for analyzing the eastern white pine resource because most white pine is manufactured into finished products that require larger dimension, high-quality raw material. Timberlands in the 17-state area contain approximately 31.5 billion board feet of eastern white pine sawtimber (Table 1).

In general, states that contain high volumes of growing-stock also contain high volumes of sawtimber. In some states, such as Pennsylvania, the opposite is true: high growing-stock volumes are associated with low sawtimber volumes. Timberlands in Pennsylvania contain approximately 494 million cubic feet of growing stock (ranked sixth in the 17-state area), but contain only 1.2 billion board feet of sawtimber (ranked tenth in the 17-state area). Consequently, predominantly small-diameter trees comprise the eastern white pine resource base in Pennsylvania and other states exhibiting this characteristic.

Three states -- Maine, New Hampshire, and New York -- account for 15.6 billion board feet of sawtimber, or 50 percent of the total eastern white pine sawtimber in the 17-state area. These three states, along with Vermont, Massachussets, Connecticut, and Rhode Island, form a contiguous region that accounts for two-thirds of the eastern white pine sawtimber resource. For this reason, we will focus on this region of the Eastern United States.

White Pine in New England and New York

New England and New York have been the traditional locations of white pine manufacturing. Regular shipments to England of white pine ship spars, harvested from New Hampshire's forests, began in 1653 (Fay 1974). As the low-density, high-strength characteristics of the species became better known, shipbuilders and other manufacturers of white pine products eventually moved to the region.

Over the years, building ships with white pine waned as this ship mast resource was depleted and sailing vessels were replaced by steam-powered ships, which were products of the industrial age. While the old-growth stands of white pine so important three centuries ago no longer exist, the species remains an important forest resource in certain areas of New England and New York.

Timberland Area

Since previous surveys in each state, the area of eastern white pine forest type has changed little. Acreages in the 7-state region have declined, but by only two percent. Area increases in some states have been offset by decreases in others.

In most states, especially in Southern New England, the timberland area of eastern white pine forest type has increased (Fig. 2). This trend is typical of land in transition from agriculture back to woodland. Here, farmland is reverting to forestland, creating increases for all forest types, but especially for the eastern white pine forest type.

Offsetting area increases in Southern New England were area declines in New Hampshire and New York. In New Hampshire, timberland area decreased from approximately 991 thousand acres to approximately 812 thousand acres -- an 18 percent decrease. In New York, timberland area decreased by 10 percent. Decreases of eastern white pine forest type may be due in part to the inability of the species to compete with hardwoods during the natural regeneration of harvested stands.

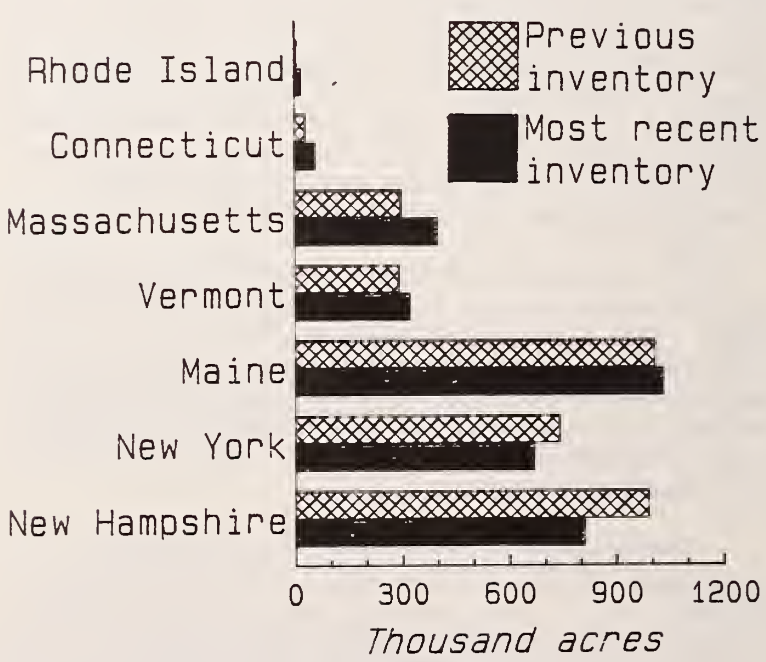

Figure 2.--Area change of eastern white pine forest type on timberland in New England and New York

Trends in harvesting of eastern white pine can be seen from two studies conducted by the USDA Forest Service. A timber industry survey was conducted in New Hampshire (Bones and others 1974) for the calendar year 1972, followed by a similar survey[2] that was conducted in 1982. Results from the two surveys showed that between 1972 and 1982, an additional 32 million board feet of sawlogs, 33.7 thousand standard cords of pulpwood, and 1.6 million cubic feet of other industrial forest products were harvested (Table 2).

Table 2.--Eastern white pine roundwood production in New Hampshire by major products, 1972 and 1982

Product	Standard Unit	Year 1972	Year 1982	Change
Sawlogs	Million fbm	96.9	128.9	+32.0
Pulpwood	Thousand cords	1.7	35.4	+33.7
Other products	Million ft^3	0.4	2.0	+1.6

Growing-stock Volume

Current resource statistics for each state in New England and New York indicate that eastern white pine growing-stock volume is spread across all diameter classes. The largest volumes are in the 12-inch diameter class (between 11.0 and 12.9 inches d.b.h.).

We analyzed the change in growing stock, but for only Maine, New Hampshire, Vermont, and New York. Data from the reinventory of the three Southern New England states is currently being processed, and estimates are unavailable.

In the four states, eastern white pine growing stock has increased in most diameter classes (Fig. 3). During the period between inventories, the greatest volume remained in the 12-inch diameter class. However, this class increased more than any other, and now shows a prominent peak.

Certain diameter classes have shown important decreases in growing stock. Currently, smaller volumes in the 6-inch and 8-inch diameter classes indicate that there are fewer small-diameter trees to form the next crop of sawtimber trees.

[2]Nevel, Robert L.; Engalichev, Nicolas; Gove, William G. The timber industries of New Hampshire and Vermont - a periodic assessment of timber output. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. [in press].

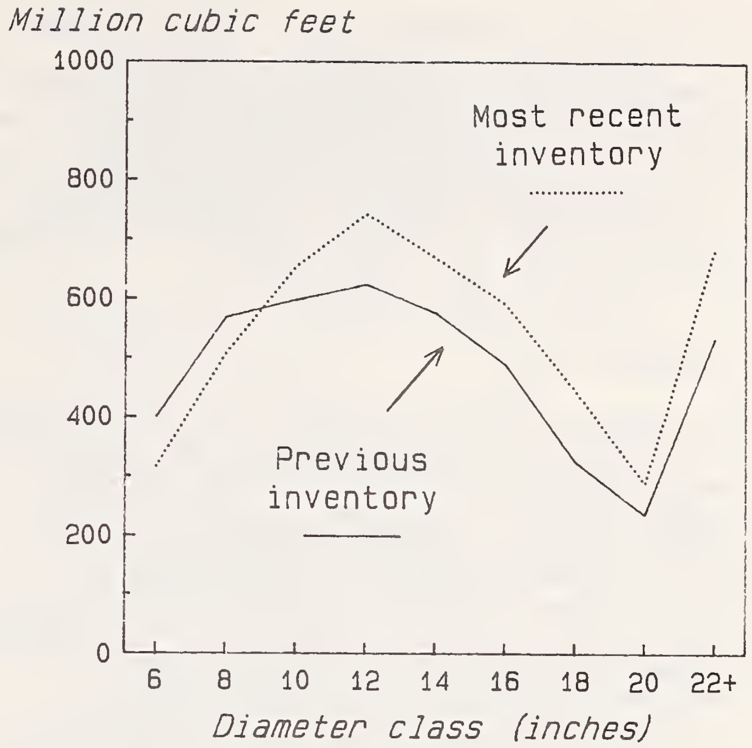

Figure 3.--Diameter class distribution of eastern white pine growing stock by inventory date in Maine, New Hampshire, Vermont, and New York

Total growing-stock volume has increased in New England and New York. Considerably less is being harvested than is growing in the region; growth is almost twice removals (Table 3). Only in New Hampshire are growth and removals in balance. There is little room for increased white pine harvesting in New Hampshire if the current level of growing-stock volume is to be maintained.

Table 3.--Net growth[a] and removals of eastern white pine in New England and New York

State	Growth	Removals
	---Million ft^3---	
Connecticut	4	--
Maine	62	37
Massachusetts	34	9
New Hampshire	39	39
New York	37	17
Rhode Island	4	--
Vermont	13	7
All states	193	109

[a]Net growth equals accretion plus ingrowth, minus tree cull increment and mortality.

In terms of growing stock, then, the eastern white pine resource shows both positive and negative trends in New England and New York. On the one hand, the resource is maturing; more trees are moving into the larger diameter classes. Also, annual growth of growing stock exceeds what is being harvested annually. On the other hand, there are fewer small trees to replace those being lost to mortality and harvesting.

Sawtimber Volume

Current resource statistics for each state in New England and New York indicate that most of the eastern white pine sawtimber volume is in large diameter trees. The largest volume is in the 12-inch diameter class, but 49 percent of the total sawtimber volume is in the 12-inch to 16-inch diameter classes. In addition, 18 percent of the total sawtimber volume is in the old-growth component (21.0 inches d.b.h. and larger), compared to 14 percent for growing stock.

Eastern white pine sawtimber has increased in all diameter classes (Fig. 4). The shape of the curve showing diameter class distribution has remained similar between inventories; sawtimber volume has increased proportionally in every diameter class except the 10-inch and 20-inch diameter classes, which showed only minimal increases.

A more important aspect of sawtimber volume is tree grade distribution and how the distribution has changed. Eastern white pine tree grades used in USDA Forest Service inventories are based on tree grading factors developed by Ostrander and Brisbin (1971): minimum scaling diameter and log length, weevil injury, face requirements, sweep or crook allowance, and total scaling deduction.

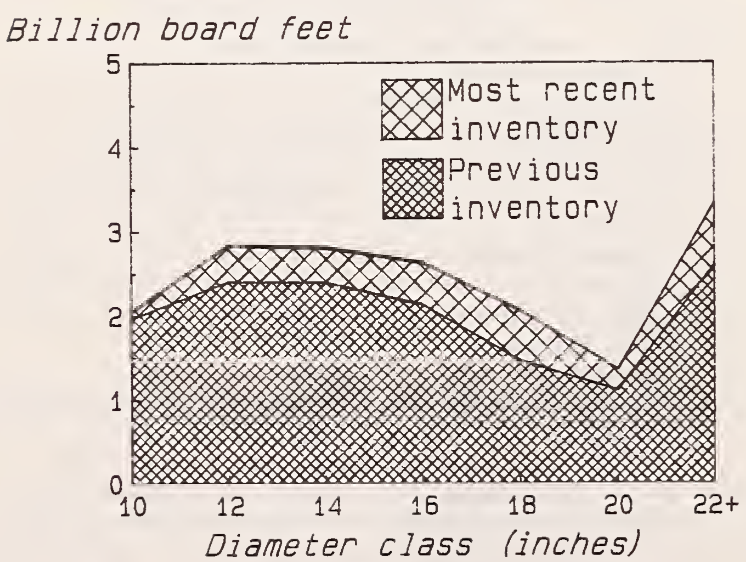

Figure 4.--Diameter class distribution of eastern white pine sawtimber by inventory date in Maine, New Hampshire, Vermont, and New York

The white pine resource of New England and New York is composed of predominantly low-grade sawtimber; 47 percent is grade 3 timber and 27 percent is grade 4 timber (Fig. 5). However, this distribution of tree grades has changed from previous inventories.

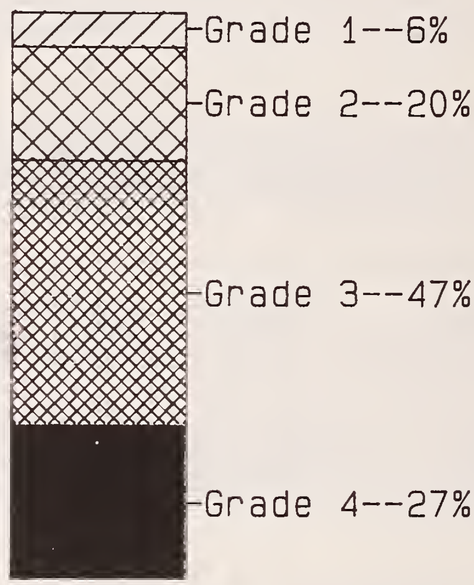

Figure 5.--Distribution of sawtimber volume by log grade in New England and New York

Sawtimber volume has increased by 36 percent in Maine, New Hampshire, Vermont, and New York, but the increase has not been evenly distributed over all grades of timber (Fig. 6). Eastern white pine grade 3 timber has increased by 25 percent, while grade 4 timber has decreased by 8 percent. The bulk of the increase has occurred in grade 1 and 2 timber.

What has been responsible for the shifts in tree grade? There are three possible explanations: First, tree grade is as much a function of tree size as it is of the condition of the tree. As trees mature, they will naturally move into grades 1 and 2. Second, tree harvesters and processors are beginning to utilize the resource more completely. When poorer grade material is removed, the trees left behind will be given the opportunity to mature into higher quality material. And finally, improved forest management by many landowners may be increasing timber quality.

To varying degrees, all three reasons contribute to changing tree grade distribution in the four-state area. As mentioned, sawlog production from eastern white pine has increased, but not as much as pulpwood and other products have. Much of the sawtimber that may be used for pulpwood and other products probably comes from grade 3 and 4 material. In addition, we have seen that the eastern white pine resource is maturing, and as it does, it will naturally become grade 1 and 2 material.

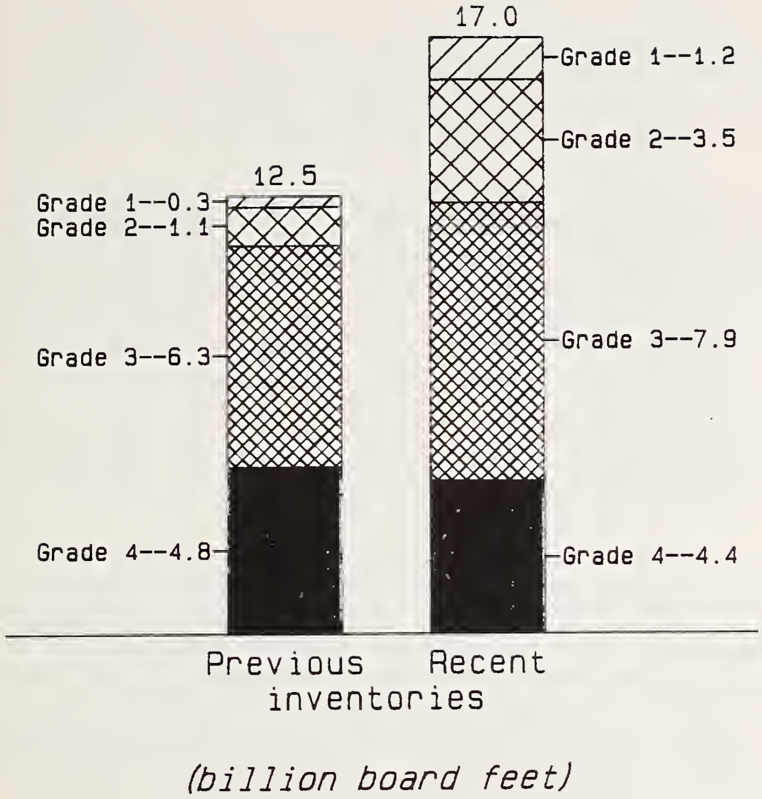

Figure 6.--Eastern white pine sawtimber volume by inventory date and tree grade in Maine, New Hampshire, Vermont, and New York

Summary

The resource statistics we have provided for eastern white pine show what we consider to be the potential supply. The economic and physical availability of this resource is difficult to ascertain given current landowner attitudes and the proliferation of local harvesting laws.

However, our analysis shows that there is a considerable amount of eastern white pine potentially available, that this resource is maturing (curves of diameter class distribution are moving up and to the right into the larger diameter classes), and that currently it is growing twice as fast as it is being removed for an increasingly wider range of forest products. While most of the eastern white pine timber is composed of grade 3 and 4 material, larger proportions of the sawtimber resource have moved into grade 1 and 2 material over the years.

There are some areas for concern, though. We must be aware that many of our white pine stands are being lost to other species, perhaps more than are being added. Stands of eastern white pine are coming back in certain areas of the Northeast, but that may not be enough to offset losses.

The decline in small-diameter trees that we are just now beginning to see may create dips in sawtimber volume several decades from now. The short-term picture seems bright, but we must be far-sighted enough to recognize and plan for changes in this dynamic and important resource.

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Where Have All the Forests Gone? Long Time Passing

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Abstract

White pine has been a significant element in our forests since the ice left 15,000 years ago. The Indian stone-age and colonial iron-age technologies made pine an important part of the economy. The need for forest regulations has provided a valuable commentary on the interaction between pine trees and people. New efforts are needed to meld technical and political processes in an information-age society.

I was asked to place white pine in an historical perspective appropriate for such a modern day conference as this, I suppose because people need roots for mental sustenance just as much as white pine trees need them for water and nutrients. In addition, it seems to me that white pine has been a particularly significant element in New England's environment which has lent strength to the fabric of our region's culture.

In The Beginning

I chose to begin this historical survey at a point that will create a properly spacious feeling of grandeur - when our modern forests themselves began - with the last stand and gradual decay of the glacial ice about 15,000 years ago. Pollen evidence suggests that plants rather promptly covered the newly exposed landscape (Davis, 1958, 1983) and animals apparently followed so quickly that the paleo-Indian hunting people were in residence as much as 9,000 years ago, judging from the artifacts they left behind (Sammartino, 1981). Up to the time of contact with Europeans at least four recognizable Indian civilizations successively dominated New England. It's hard to know how these stone age folks interwove their lives with those of white pine. However, the paleontologists assure us that white pine was much more plentiful 5 to 8 thousand years ago during the hypsithermal. For a people heavily dependent on hunting this cannot fail to have affected their lifestyle. Whether they, in turn, affected the white pine is more speculative, but presumably man-made forest could have been quite widespread under the warm, dry climatic conditions that then prevailed. So it seems safe to conjecture that this period was the one when the interaction between white pine and people really began in earnest.

However, forest vegetation soon changed again in response to climatic drift and white pine seems to have declined to something like its present abundance a couple of millenia ago. If our bogreading experts are right, it appears that this conference is about 8,000 years too late to deal with our largest pine population; that is already long gone. I am sure some futurists among us could say we are preparing for the next hypsithermal, while others will say, "Forget it, another glacier will slip down on us first".

A good deal of popular wisdom tells us some of the ways trees fitted into the daily lives of the Indians at the time of contact with Europeans. Although they did a lot of hunting and fishing, about half their food came from farming, mostly on some of the annually flooded intervales (Cronon, 1983). Birch bark was used for cooking utensils, containers and canoes. Spruce roots and pitch were also used to join and seal the bark. Hogans were made from saplings covered with bark or skins. Maple produced sugar and oaks contributed a kind of flour, while other nuts and berries were welcome additions to their diet. It seems likely that white pine could have been easily worked with the primitive tools available to produce a variety of utensils and sturdy dugouts. Fish weirs were made from small saplings (Whitehill, 1959). This all seems reasonable but I haven't found too much carefully researched literature to document these uses.

The Colonists

Once we leave the prehistoric, however, the written word on white pine and people abounds. Early explorers were all struck by the richness of the New England forests. Many commented on the ease of getting through the woods near the southern New England coast, perhaps because of repeated Indian burning. Those who traveled inland, however, were more apt to think in terms of a "howling wilderness" and complain about the difficulty of getting through old blowdowns.

Modern thought suggests that these early arrivals saw much the same suite of trees that we see today, growing in the same environmental niches where they now thrive (Raup, 1964). After due allowance for changes in common names the species mentioned by the reliable observers generally bear out this conjecture (Whitney, 1793). Thus it seems likely that the vegetation zone map put out by the New England Society of American Foresters would look quite reasonable to these early travelers. Here we find the northern hardwoods separated from the central hardwoods. Significantly, for our purpose here today, white pine and hemlock are hyphenated appendages to each of these main species

assemblages.

Although there seems to have been considerable stability in the species mix found throughout the region, by way of contrast there has been great instability in the species which happen to dominate a given acre at any point in time. Local dominance seems to have been a function of how fires, storms or other cataclysms have impinged on existing stands of trees. Because white pine, like red maple, can exist on practically all sites, from the dryest to the wettest, it is very opportunistic and able to exploit any bit of unused space in the sun. Thus the patch work of forest openings created by intermittent storm winds and fires in New England has provided plenty of places where white pine can gain a foothold throughout our hardwood forests. Research has shown that the Harvard Forest Pisgah tract, for instance, was covered with hardwoods which blew down in the early 1600's and then burned. This set the stage for white pine and hemlock to take over until they, in turn, were blown down in 1938, to be succeeded by a stand of northern hardwoods (Swan and Henry, 1967).

Pines can often dominate the dry outwash plains but on upland tills the bulk of our original white pine probably occurred as scattered individuals or small groups in a sea of hardwoods. Many of these pines became super-dominants whose great size caught the commercial eye of early visitors like John Smith, Raleigh Gilbert and George Popham (Malone, 1964).

That thoughts of commerce were not confined to the colonists is evident from the fact that as late as 1880 when Charles Sprague Sargent mapped the forests of the United States for the 10th Census, he classed all of New England as the Northern Pine Region (Sargent, 1884). That he recognized his own bias appears in a second map of vegetation on which he divided the region between the Coniferous Forest to the north and Deciduous Forest in the south. A truer picture was produced by Merriam in 1898 when he mapped natural vegetation to guide settlers in their selection of crops likely to prosper in the climate of a new land (Merriam, 1898). He showed the Boreal Region in northern New England, the Carolinian Zone (central hardwoods) in the south and the Transition Zone between. This general configuration has been recognized by most plant geographers ever since and is the basic framework for the SAF map of Natural Vegetation Zones (Westveld, 1956).

These then were the kinds of trees found by the first Europeans, in age-classes that were largely a patchwork set by catastrophes. The whole forested landscape must have seemed endless to people used to the crowded dimensions and severely rationed resources of Great Britain and the Continent. Their immediate needs were for food and shelter, and although the Indians had done fairly well with hunting, fishing and farming, the colonists had a hard time adapting old world methods to new world conditions. Their vision of the good life was epitomized by the tidy agricultural landscapes and buildings of home and they set out to clear land and reproduce the culture they had left behind. In this context forests represented an opportunity to make, on this side of the ocean, a new kind of landscape, supporting a new kind of economy and a totally new kind of social order.

Although subsistence farming was the first order of business, a close second was keeping creditors back home placated. Without a continuing flow of goods and services from the home country the settlements would have failed. Fish and, to a limited extent, furs were available together with such wood products as clapboards and pipe staves. The white pine along the coast could be cut and split into the former, while white oak made excellent cooperage. These two, along with pot and pearl ash from the trees cleared to make farmland, became important items of international trade and of debt service.

Forest Regulations

That colonial success depended to some significant degree on careful use of their accessible trees is evident from the earliest recorded forest regulations. The popular myth about pioneers being fiercely independent individualists obscures the fact that the colonists were all too willing to regulate the minutest details of everyday life. It was commonplace for governments to set wages and prices in addition to dress and behavior codes. It is not surprising, therefore, to find that Plymouth in 1626 prohibited the export of any forest products without a license. Presumably this was to conserve nearby timber for local necessities. By 1658 the laws of Plymouth were expanded to insure that cut trees were promptly sawn or split into products, again to avert waste. Similar regulations, along with others aimed at controlling damage from forest burning, appeared in most of the colonies (Kinney, 1916).

As the trade in wood products became more important, various colonial laws set specifications designed to insure the good reputation of their wood products in world markets. Massachusetts set the length and quality of pipe staves for export in 1641, the size of a cord of wood in 1647, provided inspectors and specifications for shingles in 1695 and for clapboards in 1727. Town surveyors of wood and bark were authorized in 1710 and still function in some Massachusetts towns. These public regulations were generally aimed not at conserving natural resources but at promoting a more vigorous trade in wood products under the prevailing mercantilist theory that exports should be maximized, imports minimized, and the balance taken in gold. Echoes of this argument for both farm and forest exports continue to rattle through the eaves of legislative halls today.

Regulations to prevent local wood shortages

and consequent hardship, or to protect individual property rights by punishing timber trespass and preventing damage from careless burning, and efforts to promote honest trade--all being self-imposed by town or colonial governments--were received with resignation if not with enthusiasm. On the other hand regulations to preserve white pines suitable for masting the royal navy and to promote the production and export of naval stores to Great Britain were set by Parliament and this was another matter. In fact, the close connection between pine trees and sea power contributed a good deal to the irritation that finally led to rebellion against the crown (Albion, 1926).

The so-called "broad arrow policy" is probably the best known of the colonial forest regulations. In fact, it was built into the charter of The Province of Massachusetts in New England given by William and Mary in 1691. All pine trees 24 inches in diameter a foot above the ground, suitable for masts and not growing on private land, were reserved for Their Majesties' use. The value of keeping all these mast pines is suggested by the fact that the same charter gave to local inhabitants four fifths of all the gold, silver and other minerals they might find on public lands.

Later, in 1704 when needs were more urgent, Parliament voted bounties for any tar, pitch, rosin, turpentine, hemp, masts, yards and bowsprits imported from the American colonies into Great Britain. These subsidies continued in one form or another until terminated by the revolution. Thus the carrot and the stick were both used by the king's ministers in their desperate attempt to use New England pines to maintain the balance of European sea power. Incidentally, this was an effort fraught with difficulties our government officials concerned with stockpiling oil and uranium might easily understand.

The ineffectiveness of the "broad arrow policy" is a fascinating case study in the difficulties of long distance administration and of communicating the real facts of a situation to a self-deluded home government. It also throws light on the problems of enforcing an unpopular law and on the need to make suitable financial arrangements for contractors. As the daily news implies many of these problems still bedevil military policy and procurement programs. I recommend "Pine Trees and Politics" (Malone, 1964) to the recreational reader and "Forests and Sea Power" (Albion, 1926) to the more serious scholar.

White pine and oak also made the New England ship building industry possible, based primarily on trees near the coast until transportation improved. This was really the major use of wood that might be called "industrial" during the 200-year settlement period which began in 1620. In this era the largest consumption of wood was for domestic purposes as great quantities were needed to build and maintain farmsteads and villages. The old post and beam construction method made good use of pine for overhead timbers, sheathing boards and shingles, together with chestnut for sills and oak for joists. In addition, vast quantities of hardwood were used to heat the drafty colonial dwellings.

All told, most of this wood came from local sources because overland transport with oxen or horses for much more than 15 miles was prohibitively expensive until the era of turnpikes and canals in the late 1700's and early 1800's. So dependent were the colonists on local wood that the Boston town meeting seriously considered moving off the peninsula because of the high cost of importing fuelwood. The situation was saved, however, by slooping wood from the tidewater rivers of Maine and the eventual appearance of coal.

Wood-Using Industries

As transportation improved, however, and the need for wood products continued to grow with the country, a real lumber industry sprang up in Maine. Again the deep penetration of the hinterland by rather sluggish rivers made river driving of pine and spruce logs feasible. Bangor became a brawling sawmilling town at the head of navigation and Maine loggers became famous as they exploited first the forests of Maine, then Pennsylvania, New York, the Lake States and the South and finally the West (Smith, 1974). All this became possible not so much because the technology of logging and milling had improved, but more because transportation was cheapened by rail, canal and the sea. This coupled with the policy of disposing of the public domain brought vast supplies of virgin timber to market in time to support continental settlement.

In central New England, meanwhile, a special event -- the decline of agriculture caused by competition from the rich soils being opened in the Middle West -- had a marked impact on the abundance and quality of white pine in the region. Throughout the Transition Hardwood-White Pine-Hemlock zone white pine was the primary pioneer species starting the old-field succession back toward hardwoods. By the turn of this century vast acreages of white pine were maturing on the land abandoned by Yankee farmers.

The pure stands of pine over upland tills were something new to the region and because the population of white pine weevils went right up along with the population of pines, sawlog quality was not very high. But the old-field stands made up in quantity what they lacked in quality, generally averaging a growth rate of about 400 to 500 board feet per acre per year, on a 60 to 70 year rotation. Such vast amounts of timber, readily accessible in a well settled countryside with an underemployed population, created industrial opportunities too good to pass up. A whole array of white pine industries ranging from heel shops, to

cooperage and box plants, to toy factories, to match manufactures sprang up in addition to sawmills. These white pine industries flourished well into the 1900's. The peak of pine lumbering came in 1909 and the container industry didn't falter until the mid-1920's when urban living changed shopping habits and wooden containers gave way to paper. Then, of course, came the 1938 hurricane and the Great Depression, a combination of disasters that marked "paid" to a great deal of New England's pine industry.

The Past As Prologue

In recent years, spurred partly by the rising cost of transportation from the South and the West and partly by European export demand, the cut of regional timber has increased. However, if the dollar remains too strong some exports may slacken and competition from imports will increase. But in the long run these problems will be solved and there is likely to be greater need for the output of local wood-using industries.

If demand may eventually wax, what about the supply of local wood? There has historically been a preponderance of hardwoods in all parts of the region, and this situation seems likely to continue, barring some climatic change. Although there is still a good deal of old-field white pine maturing, farmland abandonment has largely ceased, so additions to coniferous forest land from this source have probably dried up. In many ways we seem to be returning to a situation much like that faced by the colonists -- a plethora of hardwoods with a scattering of pine and hemlock, except on the dry outwash plains where conifers dominate. Because this scenario shows pine and hemlock in the minority it will be useful to learn all we can about how these species have maintained themselves in the past on various forest sites.

A major lesson from the past is the fact that catastrophic events have played a central role in shaping our forests. In addition, both land use and wood utilization have fluctuated enormously in response to effective demand and to technological innovation. Also, when looking back, it is clear that the events that have had truly significant impacts on society have been largely unforeseen in any long run view of the future held by ordinary folks, business people, government officials, planners or divines. Because this is a permanent feature of reality, management plans of all kinds must be designed to cope with radical and unexpected change as a normal part of everyday life.

Fortunately, we are in a better position than ever before to collect and process information about forest resources in a timely fashion. However, it is clear that we have not discovered the companion techniques needed for wise consensus building to replace the slow processes used by our ancesters. I believe that success in creating a new and more effective melding of political processes with modern views of biophysical and social reality will largely determine the future of New England's forests.

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QUALITY ISSUES AND ALTERNATIVES

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My presentation will first deal with those topics that I feel are most important to the manager who is concerned with producing high quality white pine lumber. Secondly, I will offer some information regarding definitions of quality in white pine and how quality can affect log procurement and lumber production. The information I will relate to you is basically an account of how our company deals with the issues of quality in the white pine resource. For that reason, I think it would help put things into perspective if I offered just a couple of facts concerning our company. We are located in south-central Maine some 150 miles north of here with a land base of about 6000 acres within a 50 mile radius of the mill. Our level of production is presently around 15 million board feet per year.

Our geographic area is not blessed with an overabundance of sites that regenerate pine naturally with any consistency. For that reason, our woodland management activities involve much site conversion through replanting. With proper planting techniques, pine is easily established and grows well on the better sites. 40 inch leaders are common in the first few years of growth. The biggest problem to overcome in order to develop these trees into quality trees is dealing with the white pine weevil. I believe weevil control activities are an essential part of a management plan of anyone seriously involved with planting white pine. Proper use of a pesticide during the early years of growth will greatly reduce white pine weevil damage. Our weevil control spray program has begun the first week of April for the past three years. Depending on weather conditions, we generally start observing the first weevil activity around the third week of April, so we try to have our spraying completed by then. We apply an emulsifiable concentrate of Lindane to the upper 1/3 of the leader (particularly the buds) with a Solo 425 backpack hydraulic sprayer. The mixture used is 4 tablespoons Lindane to 3 gallons water. This treatment has reduced the incidence of weevil-affected trees from as high as 60% in some plantings to an annual rate of around 10%. At a cost of $13.00 per acre (or .03 per tree at 400 trees per acre), this is an investment for quality we can well afford to make. In addition to the spray treatment, we also go over all our plantings in late June or as soon as weevil damage starts to show up and perform corrective pruning where needed at a cost of $10.00 per acre. The importance of this corrective pruning where needed should not be overlooked. In just a minute's time, one can restore the form of a tree which was probably destined for pulp mills to a single stem with log potential.

The other major investment we make in improving the quality of pine on our lands is pruning. There have been at least two different studies conducted by Maine Forest Service Personnel that document the rate of return after inflation for the pruning investment at around 13.5%. These studies were based on a time of ten minutes required to prune to 17 feet. Current costs of pruning white pine to 17 feet seem to be in the neighborhood of $1.00. Recently we had an opportunity to see an example of what pruning can do to grade recovery in white pine. One of our log suppliers brought in a couple of truckloads of logs that had been pruned around 30 years ago. The total volume amounted to a little over 10 thousand board feet. We did a grade recovery study on these logs and discovered the following. The percentage of D Select and better lumber recovered from these logs was 23%. Our average annual recovery of selects never tops 5%. The recovery of Finish and Premium grades varied little from our norm; pruned 6.6 versus 7% norm and pruned 28.8 versus 25% norm. The increase in select grade was accompanied by a corresponding decrease in the % of standard; our average annual recovery of standard grade being 58%, that of the pruned logs being 38%.

On the subject of producing quality pine trees, there is much to be said for the benefits of competition in the first 20 years of growth. Increased levels of shade is known to discourage weevil activity and denser stocking levels will force young pines to grow up rather than out when weevil damage does occur. We subscribe to the theory of prolonging the time before the first thinning and perhaps sacrificing some diameter growth to gain height and quality of the stem. For these reasons, we feel a certain level of competition from hardwoods and particularly fir to be beneficial in our plantings.

Not to be overlooked is the potential value of naturally established white pine in mixed stands. In our area, some of the best quality white pines are often found in mixed stands of fir, spruce, hemlock, and to a lesser degree, hardwoods. Seeking out these trees, making the pruning investment on them, and in some cases performing crop tree release should be part of an overall management plan for developing quality white pine trees.

At this point, I would like to move on to the topic of log grading and what exactly log quality means to a mill such as ours. First of all, the pine log market in general can be termed as a buyer's market. There is an abundance of pine logs available at this time[1/]. However, the percentage of lower grade logs on the market far outweighs that of the higher grade logs. One of the main reasons we buy our logs by grade is to try and give our suppliers an incentive to bring us the best quality logs they can. I hope the fact that more and more mills are going to grade purchasing of pine logs will help to encourage landowners to manage for quality.

Our log grading system is categorized into four grades and accordingly, four prices. We grade out logs as Select, #1, #2 or #3. To be graded select, a log must be 16" or greater at the top end and have no knots greater than 1/2". All knots 1/2" and less are disregarded and no other defects are allowed. Our #1 grade has a minimum top of 12". The log is restricted to a maximum of four red knots up to 3" diameter and no other defects are allowed. Our #2 grade has a minimum top of 10" and a maximum red knot size of 4", not limited in number. Other slight defects are allowed. Our #3 grade has a minimum top of 7". Knots can be up to 4" in diameter on a 12" and proportionally larger on larger logs. Other defects are allowed.

We want a log graded select to produce a reasonably high percentage of D Select and better grade lumber; hopefully, at least 25 to 30%. Grade 1 logs should produce lumber predominated by finish and premium grades. Grade 2 logs should contain mostly premium grades with a lesser percentage of standard. Grade 3 logs usually produce lumber grades no higher than standard. In 1984, the grade breakdown of our log purchases was as follows: Select 4%, #1 14%, #2 37%, #3 29% and 8 foot logs 16%.

At this time, there is a price differential of $90/MBF between the mill delivered prices of our lowest and highest grades. Manufacturing costs of lumber generally do not vary with grade. Without getting into a detailed account of current lumber prices, I would just like to point out that the difference between the wholesale selling price and the total costs of production in select and finish grades in the neighborhood of four times that same differential in the standard grade. This is our incentive for managing for quality pine on our lands.

[1/] Although the Forest Statistics for Maine 1971 and 1982 report shows a decrease in the area of sapling and seedling type pine stands by 83% over the past decade. This fact, along with increased Canadian competition for pine logs, leads me to believe that we will be looking at a shortage of pine logs in the not too distant future.

SOIL-SITE RELATIONSHIPS FOR WHITE PINE IN THE NORTHEAST[1]

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Abstract

Foresters have continuously sought to understand the relationships of the growth of white pine to environmental factors. Early descriptive accounts of adaptation of white pine on various soils were followed by quantitative studies of the influence of site factors. Results of various studies have much in common. Most show better growth on more poorly drained soils, on soils with better moisture storage, and on soils with more surface horizon stones and lower stone content in lower horizons. Soil properties have proven effective for predicting site quality accounting from 60-80% of variability in growth. Soil classification units and habitat types have also been examined for use in predicting growth of white pine. None of the studies have resulted in a widely tested or adopted system for evaluating biological suitability or economic viability of white pine management on various sites. However, the studies have provided a good knowledge base about white pine growth and how it relates to site so that those goals are within reach.

The importance of white pine (Pinus strobus L.) in colonial days and up to about 1870 in the Northeast is legendary. The wide boards of floors and walls in early homes testifies to the size and stature of the trees from which they were sawn. Occasionally we get a glimpse of such specimens with diameters of 4-5 feet (1.2-1.5 m) and heights of 150 or more feet (46 m).

Frothingham (1914) put it very well when he wrote, "Of all the trees of eastern North America white pine best combines the qualities of utility, rapid growth, heavy yield, and ease of management." In long-term growth potential no other species in the region matches white pine. The yield table data of Leak et al. (1970) show volumes of fully stocked stands on good sites (SI_{bh50} 80 ft) at age 60 of about 51,000 board feet per acre. Those volumes require annual growth rates on the order of 1,000 board feet per acre if early stages of growth are excluded. In well-stocked stands white pine far outproduces our major hardwood species in board foot volume.

White pine grows well on a wide range of sites. It is well adapted to poor sandy soils and out-competes most other species on them in the absence of fires. On medium and fine textured soils it is not as dominant naturally, except in old field situations, but is extremely productive. White pine is also able to grow well on the better drained micro-sites of many poorly drained soils, and on stony ridges with shallow soils. It grows well in both pure and mixed stands, and in southern New England is the second most important species in terms of volume, accounting for about 20% (Leak et al. 1970). White pine responds very well to thinnings and can be managed in very low density short rotation systems as shown by previous work (Hunt and Mader 1970) and the report on the same studies included in this symposium. The high volumes per acre and relatively good stumpage values result in high dollar values per acre for white pine at relatively short rotations, increasing its attractiveness for management. The relatively good growth and quality and ease of regeneration on poor sandy soils make it a preferred species for those areas.

The many favorable characteristics cited above, the wide range of productive potential on different sites, and the general suitability of white pine for widespread, active management makes an understanding of site factors and site productivity of much more than academic interest for white pine, and accounts for the long history of site studies for the species in the Northeast and Mid-west. In his bulletin "White Pine Under Forest Management" in 1914, Frothingham gave an excellent summary of the general growth of white pine on different soils.

Goodlett (1960) presented an interesting discussion and Table showing the "Lines of Descent of Site and Soils Classification at the Harvard Forest, 1911-1952". Site differentiation progressed from "better" vs. "lighter sandier soils" through several configuration of heavy, medium and light soils to a 5-drainage class system with some pan differentiation but work there was never translated into a regional quantitative site prediction system.

The advent of quantitative soil-site prediction equations for white pine in the Northeast was marked by the work of Young (1954) in southeastern Maine who introduced the methods developed by Coile in the Southeast, employing multiple regression models to predict height from functions of age and site variables. His results showed relationships of height to depth of A-horizon (inverse) and amount of stones in the B-horizon (inverse). Two subsequent studies were made in the same area, one by Czapowskyj and Struchtemeyer (1958) and one by Stratton and Struchtemeyer (1968), the latter part of the regional study sponsored by the U.S. Forest Service (Leak et al. 1970). The latter study identified eight soil variables related to height growth in addition to age: soil drainage class, pH of surface mineral soils, thickness of A,

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available moisture capacity of the surface horizon, bulk density in the B, and available moisture in top 30" of soil. R values of five and six factor regressions reached about 0.89.

Husch and Lyford (1956) carried out a similar study in southeastern New Hampshire. Their equation for predicting height included only age at bh, basal area per acre, and drainage class. Within the range sampled from excessively to very poorly drained, greater height growth occurred on more poorly drained soils. The equation had an R^2 value of 0.81 and standard errors of estimate of about 1.8% of mean stand height.

The results of the Massachusetts portion of the regional study (Mader 1976) included several prediction equations for site index, height, cubic volume growth, and board foot volume growth. Several data sets of increasing complexity were also tested. Most of the relationships corresponded with ones of previous studies; i.e., better sites had higher pH in B- and C-horizons, poorer soil drainage, more stone and gravel in the surface soil, less in the subsoil, more N in the A horizon and profile, and less silt and clay in the B-horizon. Regressions of height on age accounted for a large proportion of the variation in height (R^2 = 0.76), a result of the relatively low range of annual height growth over a wide range of sites. Addition of site factors to age added about 12% to the variation accounted for, similar to several previous studies.

The results of all of these studies show some consistencies, and some contradictions. Better sites were generally related to poorer soil drainage classes although Stratton and Struchtemeyer (1968) reported poorer growth on somewhat poorly and poorly drained soils. Logically, higher moisture availability and reduced moisture stress on wetter soils should maximize photosynthetic efficiency and duration. The effects of very heavy thinning on growth patterns (Hunt and Mader 1970, Mader 1978) and slope position effects (Mader 1978) support this view. Finer soil texture and better water holding capacity of surface soil was generally related to better sites with the exception of Husch and Lyford's (1956) study where soil texture was not significant. Texture of the B-horizon was not consistently related to site quality in various studies. Mader (1976) found increased silt and clay in the B-horizon associated with poorer site productivity, Husch and Lyford (1956) found no significant relationship, while Stratton and Struchtemeyer (1968) report no significance for silt and clay content in the B-horizon but do note a positive association of water-holding capacity in the upper 30" to site productivity. Finer texture in surface soil should provide not only better moisture availability, but also is associated with higher organic matter and fertility. It has not proven a very strong predictive factor perhaps because of the relatively small differences in water-holding capacity in A-horizons (Mader 1978). The negative relation between productivity and finer texture of B-horizons found by Mader (1976) may be related to poor root growth caused by the effects of high bulk density on aeration and compactness of the subsoil, echoing the relationships reported by Coile (1952) for southern pines on heavy soils. The association of stone and gravel content of soil to site quality, reported by Young (1954), Stratton and Struchtemeyer (1968), and Mader (1976) are interesting. Higher content of stone or coarse material in the B-horizon of poorer sites may reduce site quality because the volume occupied by the coarse material presumably contributes little to fertility or moisture supply. The reason for the association between stone content of the A- horizon and higher site indices probably lies in some association of stone and coarse material content with the inherent fertility or physical characteristics of the rest of the soil. Stonier glacial till soils may be finer-textured and more fertile than outwash materials. However, stones may have unrecognized effects on physical properties.

Humus layer development in white pine stands is related to site quality (Mader and Lull 1968) although it is less desirable for site quality prediction because of its instability. Humus depth increases with stand age and decreases with site quality, suggesting more rapid decomposition and incorporation on good sites.

Nutritional status of soil, except for pH, which reflects base saturation, has not been related to white pine site quality except for Mader's (1976) results. Stratton and Struchtemeyer (1968) found higher pH values in the surface mineral soil associated with poorer site quality, while in Mader's studies better sites had higher pH values in the B- and C-horizons. The reasons for these differences are not clear. Higher pH normally reflects better nutrient availablity and better conditions for nutrient cycling from organic residues. Mader (1976) found that better sites had more N in the A-horizon or the profile, and more organic matter in the B, but less in the A, perhaps indicating C/N ratio effects on N availability. Stratton and Struchtemeyer (1968) report better sites as having thicker A-horizons which may provide more moisture, nitrogen, or other nutrients. These tend to be correlated and their effects difficult to separate.

Fertilization studies for white pine have not shed much light on the role of nutrition in site quality. Potassium and magnesium deficiences may occur on coarse-textured outwash soils (Xydias and Leaf 1964), but such deficiencies do not appear to be widespread. Their studies showed negative responses to N fertilization and the role of nutrients on various sites is still unclear.

The main purposes of site studies are to classify sites and predict productivity, in a practical and feasible way. Site studies should also contribute to better understanding of the factors controlling growth on various sites.

Past studies may be grouped into those dealing with soil types or phases, with habitat types, or with quantitative soil-site factor analysis. The SCS Soil-Woodland Correlation data base system provides average site index values for particular soils for the Soil Survey Reports. The reports are readily available and the values are useful in a broad sense but may not be accurate for specific locations because of mapping and site quality variations. Foresters often find site index values too inaccurate for prediction of productivity on particular sites. This data base does not directly identify the site factors which influence growth. Many quantitative studies involve drainage class data, textural information etc., which could be related to soil types or phases but that has not generally been done.

The few habitat type studies (Stout 1952, Leak 1978) have been focused on species or forest type relationships to habitat rather than comparisons of productivity of species on all sites. The studies re-emphasize the prevalence of white pine on coarse, outwash soils and give site index values for them (Leak 1978) but the information is limited the causes of productivity differences are not addressed.

The quantitative site factor studies have provided effective prediction equations and insight into the influence of site factors on growth, but have not provided easy practical methods of site quality identification. Practical systems of soil identification, sampling, analysis, and interpretation have not been worked out nor implemented. Development of practical site quality identification systems should be a high priority goal of forest site scientists in the Northeast.

One possibility is the development of productivity information for white pine and other species for soil types or groups of soils by determining the variation in growth and how it is related to soil-site factors. Currently white pine site quality in relation to soil properties of the Hinckley series is being studied at the University of Massachusetts. Such information should enhance the use of soil maps for site quality estimation based on supplementary soil examination and analysis.

In conclusion, a summary of current knowledge of site quality for white pine follows. On coarse, sandy soils white pine is clearly the species of choice. These low to medium productivity sites are its natural habitat. It grows well, regenerates naturally, produces high volume and value and competes easily. On medium textured soils, i.e. loamy sands and sandy loams, white pine will generally out produce most of our other native commercial species in both volume and value. However, it is usually not the dominant component on such sites except in old-field succession but occurs as a lesser component mixed with a wide variety of other species--which compete well on these sites. Silvicultural investments to increase the proportion of white pine are justified on many of these sites. On "good" sites, i.e. fine sandy loams, loams, and silt loams, especially the poorer drainage classes, the case for white pine is less clear. It has very high productivity on such sites, but usually occurs only as individual trees or small groups. To maintain pine requires major investments for regeneration and control of hardwoods. On these sites pine may be matched in terms of value return by valuable hardwood species. However, white pine may still have major advantages in potential for short rotation and high quality under intensive management (Hunt and Mader 1970).

Clearly the better we understand and can predict the adaptations of white pine on different soils and sites, the better job we can do in deciding where and when to grow it, and the kind of silviculture to practice. All of which argues for renewed effort and research to gain even better knowledge about this most versatile and valuable species.

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THE GENETIC IMPROVEMENT OF EASTERN WHITE PINE

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The results of tree improvement research in eastern white pine are reviewed in the areas of species hybridization, blister rust and weevil resistance, provenance studies, vegetative propagation and cloning, and plus tree progeny trials. The potential of breeding for pest resistance, growth intensity and improved lumber quality is discussed. It is concluded, that significant genetic gains can be realized in all of above areas in the near future by continuing with research and bringing the long term investments made to fruition.

Introduction

Eastern white pine (Pinus strobus L.) grows over a wide range of Eastern United States and Canada. In the original forest, eastern white pine attained large sizes and was an extremely valuable timber tree. In todays forest, it grows in mixed stands, it can be an old field tree, and it is a plantation tree.

Despite interest by silviculturists, the genetic improvement work with eastern white pine has started relatively late. By the 1950's, information was available on research in hybridization and blister rust resistance. The provenance and inheritance data are from more recent experiments (Wright 1970). Reviews of genetic improvement in eastern white pine (Wright 1970; Garrett 1981; Zsuffa 1985) show focuses on the following topics: species hybridization, blister rust resistance, weevil resistance, provenance studies, vegetative propagation and cloning, and plus tree progeny studies.

Species Hybridization

Hybridization experiments in eastern white pine were pursued since the 1940's.

Earlier studies aimed at establishing the crossability between species. Later, combinations of species were tried to introduce resistance to blister rust and weevil, and for hybrid vigour.

By now, the species crossability patterns and the hybridity barriers are known in section Strobus. Reviews of results include Bingham (1967), Wright (1970), Heimburger (1972a), Kriebel (1972a) and Garrett (1979).

P. griffithii, P. parviflora and P. peuce are known to be more resistant to blister rust than P. strobus, and this resistance is inherited in some of their interspecific hybrids (Heimburger 1972a). Especially well known for blister rust resistance is the P. griffithii x strobus hybrid, with its reverse cross, backcrosses, and multiple hybrid crosses maintaining the resistance (Heimburger 1972a, 1972b; Garrett 1981; and Zsuffa 1985).

P. peuce and P. monticola indicate at times better resistance to weevil than P. strobus. (Heimburger and Sullivan, 1972a, 1972b; Wilkinson 1981). Some interspecific hybrids of these species with eastern white pine could be of promise in this regard, as well.

Eastern white pine grows vigorously in favorable environments and few exotic white pines can outgrow it. Promising are in this regard some sources of P. griffithii, P. monticola, P. ayacahuite and P. strobiformis (Garrett 1979, 1981). Interspecific hybrids of several of these species with eastern white pine have been produced and tested on a limited scale. In some trials in southeastern Canada P. griffithii x strobus, at 6 yrs of age, outgrew the eastern white pine control by 61% (Zsuffa 1976). In northeastern United States, after 15 growing seasons, P. strobus was at least as good as its hybrid with P. griffithii (Garrett 1981). Further experiments, with broader selection of parents, and more thorough testing of hybrids, seem warranted.

Breeding for Blister Rust Resistance

Blister rust (Cronartium ribicola J.C. Fisch ex. Rabenh) is an introduced disease of eastern white pine. It was brought to eastern Canada from Europe around the turn of century, spread rapidly and caused large damages.

Control of the disease was attempted by various methods, but breeding for resistance remained the only effective way in the high rust hazard zones (Anderson 1973). Investigations in United States (Charlton 1963; Van Arsdel 1964) and Canada

(Haddow 1969) concluded that the blister rust infection hazard was dependent on local climate. In the low-rust-hazard zones, blister rust does not cause serious losses and can be largely ignored. In the intermediate-rust-hazard zones, losses can be reduced by maintaining an overstory and by pruning juvenile trees. In the high-rust-hazard zones, planting of blister rust resistant varieties, or avoiding white pine planting in the lack of such varieties, are the only solutions.

Much effort has been devoted to development of genetic resistance to white pine blister rust in both USA and Canada. The work and problems are well summarized in the "Proceedings of a NATO-IUFRO Advanced Study Institute on Biology of Rust Resistance in Forest Trees" (1972) and more recently, for P. strobus, by Zsuffa (1981a).

Selections of eastern white pines for the absence of disease symptoms, and artificial inoculations of their grafts and offsprings with blister rust did not indicate any major gene effects for resistance. The observations lead to the conclusion, that the blister rust resistance in P. strobus was of polygenic nature, and that several generations of breeding were needed to increase the proportion of resistant offsprings to practical levels (Riker et al 1943; Heimburger 1972b; and Zsuffa 1981a).

More direct results were obtained by introducing resistance from another species, through interspecific hybridization. In particular, hybrids between P. strobus and P. griffithii have demonstrated immediate practical levels of resistance (more than 20% of inoculated seedlings surviving), with advanced generations of hybrids maintaining or increasing the level of resistance (Heimburger 1972a; Zsuffa 1976). Promising results were obtained also in P. strobus x peuce and P. strobus x monticola combinations. Some of these demonstrated increased blister rust resistance as well as resistance to weevil (Wright 1970; Kriebel 1972b).

Field tests indicated that offsprings which succumbed to highly concentrated inoculum could be tolerant to moderate field levels of rust hazard. Half-sibs of blister rust resistant P. strobus mother trees succumbed in similar numbers to artificial inoculation (the average survival was 2%), but survived and remained unaffected by blister rust in much larger numbers in field plantings (healthy trees from 30% to 100%, average 72%) (Zsuffa 1981a). However, for areas of high rust hazard, only the introduction of resistance from another pine species, recurrent breeding of selected disease-free P. strobus, or cloning of resistant ortets (Zsuffa 1973) can offer solutions.

Breeding for Weevil Resistance

Weevil (Pissodes strobi Peck) is an indigenous pest of eastern white pine. It kills the terminal shoot of the tree, reduces growth and seriously affects form and quality. An effective method of weevil control may be the use of trees resistant to weeviling.

Since the 1950's, there has been interest in developing strains of eastern white pine resistant to weevil. The work emphasized correlations between attack and phenotypic characters such as position in crown canopy, leader diameter, bark thickness, depth of outside and inside resin canals and oleoresin chemistry (Wright 1970; Wilkinson 1981).

Eastern white pine trees with narrow crowns and slender leaders were found to be more immune to weevil attacks than were those with thick leaders. While the selection of the former type is possible, the thickness of the leader and the width of the crown may vary greatly with environment, especially with stand density and shading. The resistance to weevils is also influenced by resin flow. However, environmental factors, such as climate and day length, may change the intensity of resin flow and thus break down the resistance (Zsuffa 1985).

Selections of weevil-free trees in natural stands and plantations were for the most part abandoned because conditions have changed in time and the trees have become weeviled. Other selected trees have not been properly tested. These include selections of fast growing trees, that have not been free of weevil attack, but have been attacked infrequently and maintained good form (Wilkinson 1981).

Observation of damage caused by weeviling in existing provenance trials offered an easy and fast method of locating resistant eastern white pines. Garrett (1972, 1973) reported, however, that although differences were observed in weevil damage between provenances of 13-year old eastern white pine trees, all sources were heavily infected. He considered it unlikely that provenances with acceptable numbers of weevil free trees can be located for use in high risk areas. Contrary to this, Genys (1981) observed some weevil free provenances in four trials of 12 -14 year old trees. The lack of consistency in data from different plantations however complicated the selection of the most resistant strains. Wilkinson's (1983) examination of data on weevilings in a provenance trial over an 11 year period identified sources with much higher than average ratios of lightly weeviled fast growing trees and concluded, that seed collections from these sources could be used in high weevil risk areas.

Some exotic white pine species, such as *P. peuce* (Balkan pine) and *P. monticola* (western white pine), show weevil resistance and could be considered for hybridization with eastern white pine (Heimburger and Sullivan, 1972a, 1972b) Balkan pine is of very variable resistance, and in several hybrids with eastern white pine the resistance broke down. Some *P. strobus* x *monticola* hybrids show promise in the United States; however the results are inconclusive (Wright 1970). This hybrid, as well as the experimented sources of western white pine, were poorly adapted to Ontario's conditions.

Physical and chemical properties of white pine oleoresin have been among the numerous characteristics investigated in attempts to identify resistance mechanisms. Concentrations of monoterpene limonene and alpha-pinene are now being considered as useful criteria in indirect selection for resistance to weevil attack (Wilkinson 1980).

Genetic Variation

Eastern white pine exhibits considerable variation in appearance in different parts of its range, a fact which suggests that as yet unidentified ecological or geographical races may exist (Heimburger and Holst 1955). The almost complete elimination of white pine stands by logging may have resulted in genetic drift in remaining small populations and in a reversion to relatively small pure populations of common parental types. Variation in certain characteristics, such as stratification requirements of seed, height and diameter growth, and response to day length, indicate this random fixation of genes and the possibility of improvement by seed source selection (Wright 1970).

Early provenance trials, in both Canada and the United States, contained incomplete and fragmented sources and gave no conclusive results (Wright 1970; Zsuffa 1985). The source of most provenance information is the USDA Forest Service's range wide provenance test, planted in the period from 1959 to 1962. Thirteen test plantations were established in USA and two in Ontario, Canada. Reports on performance of eastern white pine sources on test sites in USA have been published after 10 and 16 growing seasons (Funk 1970; Garrett *et al* 1973; Demeritt and Kettlewood 1975). On test sites in Canada results after 7 and 12 years have been reported (Fowler and Heimburger 1969; Zsuffa 1975a).

Growth data from test plantations in USA at 10 years indicated that southern Appalachian sources would do well in all but the northernmost locations. Selections of southern Appalachian white pine offer high volume production and reduced branchiness. Based on that information was the recommendation that such sources (from 34° to 36° N lat.) be planted as far north as central Pennsylvania (41° N lat.). Growth data collected at 16 and 20 years gave similar results (Garrett, 1981).

Several other characteristics were looked at. Needle length was greatest in southern sources. Central and northern provenances produced more cones at an earlier age than southern provenances. Most individual trees had the typical flat branching habit, but fastigiate types not related to provenances occured. Southern sources had fewer branches than northern sources in northern plantings. Frost and snow damage was unimportant as far north as latitude 45° N.

On Ontario test sites as well, no external frost damage was observed on any of the provenances. The southern Appalachian white pine was the best on one of the test sites (42° 40' N. lat.), while on the other more northern test site (44° 30' N. lat.) it ranked similar to Pennsylvania, New York and Nova Scotia sources. No conclusive recommendations resulted as yet from these test plantings.

Genys (1968) started the University of Maryland rangewide provenance test in autumn, 1962, with seeds from 99 stands. Data on these trials was published by Genys *et al*, (1978). Provenances varied in growth rate, ability to survive, susceptibility to blister rust and weevil, number of trees with cones, time of leaf-burst and general appearance. Several strains showed above average growth in nearly all test plantations. Such were especially a North Carolina and a southern Ontario source. Heights at all distant test sites, including Australia and New Zealand, were correlated with average height for the entire experiment.

Lee (1974), Gilmore and Jokela (1978) and Olson *et al* (1981) studied the relationship of wood specific gravity, height, and diameter of eastern white pine to geographic source of seed. These studies found negative correlations between specific gravity and both height and diameter. The differences in specific gravity among sources were slight.

The genetic structure of eastern white pine was investigated by starch gel electrophoresis sampling of the Forest Service's range wide sources (Ryu and Eckert 1983). Multivariate data exploration of isozyme data resulted in four provenance clusters, three of which may be representative of populations adapted to differing geographic and climatic conditions. Some ecotypic variation was indicated in the southern Appalachians and in the northern part of the species range.

Vegetative Propagation and Cloning

Cloning, by preserving and copying outstanding and desired genetic combinations, can provide a shortcut in breeding and can secure large, immediate genetic gains. Cloning may offer also a solution for the fast development of selected superior genotypes of eastern white pines and its interspecific hybrids resistant to blister rust and weevil. Cloning can be done by vegetative propagation. White pine does not propagate vegetatively under natural conditions. However, scions from the crowns of mature trees can be grafted readily on young stock. Also, small cuttings of the last season's twigs from young trees will root fairly readily.

Cloning of white pines could be effectively accomplished by rooting of stem cuttings or needle bundles with fascicular buds. Trials described by Zufa (1972) showed that: (i) cuttings and needle fascicles of eastern white pine can equally be rooted; (ii) bud formation can be induced in needle fascicles by pruning the terminals in early summer; (iii) propagules taken from lateral branches rooted better than those taken from terminal shoots and grew as vertical as the terminals; (iv) rooting ability of P. strobus did not decrease significantly to 10 years of ortet age; and (v) clonal variation in rooting ability existed, and became more pronounced with age. Many of these findings coincide with those of Thiman and Delisle (1939), Snow (1940), Deuber (1942), Thomas and Riker (1950), and Patton and Riker (1958).

In rooting trials of a series of P. strobus and P. griffithii x strobus ortets over several years, Zsuffa (1973) observed a consistency in rooting of the same ortets in several trials. This allowed for the selection of easily-rootable white pine clones. The possibility for selecting good rooters existed even in ortets which were 15 years of age. Hedging of rooted cuttings secured propagules which maintained rooting ability to date. Kiang and Garrett (1975) rooted eastern white pine cuttings from trees as old as 17 years. They also established that the rooting success was related to genotype of individual donor trees; they found good rooting trees in all seed sources examined in Forest Service's provenance trial.

Possible genetic gains in clonal selection of P. griffithii x P. strobus were calculated on the basis of eight clones of a half-sib in a clonal trial, at 14 years of age (Zsuffa, 1975b). Variation between the largest and smallest clones amounted to 52% in tree height, 109% in diameter (DBH), 61% in branch length, and 37% in branch angle. The clonal variance ratios were significant for each trait. The genetic gains for these traits in clonal propagation were predicted from 11% to 15%.

Plus Tree Progeny Studies

Eastern white pine is one of the more widely planted trees of eastern Canada and northeastern United States. Genetic improvement programs, aimed at seed production for plantings, deal usually with clonal seed orchards. Gaining information on combining abilities of clones placed in seed orchards is important to identify and eventually remove parent trees which yield seeds and produce progenies with inferior characteristics.

There are various methods of progeny testing parent trees in seed orchards. The most reliable information could be obtained from full-sibs, produced by controlled hybridization according to specific mating designs, on specific combining abilities. A simpler method yielding information on general combining ability is by testing open-pollinated half-sib progenies of each maternal clone in the seed orchard. Although eastern white pine seed orchard establishment is making a fast progress in both Canada and United States (Miller 1973; Genys and Hunt 1981; Rauter 1981; Zsuffa 1981b) the information on progeny testing is scarce.

Genys and Hunt (1981) studied first year growth characteristics of open pollinated eastern white pine progenies from seed orchards in seven northeastern states. Significant differences in maternal clones were observed in seed weight and first year height growth of progenies, the seed weight being significantly correlated with first year height growth. One-year height means varied from 6.6 cm to 11.1 cm. These differences in growth rates among clonal progenies warrant the continuation of tests, and poor performer clones should be the prime candidates for roguing. Such decisions could be reasonably made after 10 to 15 years of observations in field trials.

In Ontario, the eastern white pine plus tree selection and seed orchard establishment program has intensified during the last decade (Zsuffa 1985). Progeny testing is in progress and, while controlled pollination of clones in seed orchards has only recently started, trials of open pollinated progenies have progressed (Zsuffa 1978). Observations showed large variation in seed weight and one-year seedling height, and a significant correlation between these two traits. The variation between the best and poorest progenies in single trials at five years of age were very significant and amounted to 100% in height growth.

The Potential for Genetic Improvement of Eastern White Pine

The results of genetic improvement research to date clearly indicate, that there

is potential for genetic gain in almost every important area. I will discuss this potential from the point of view of breeding for blister rust resistance, weevil resistance, intensity of growth, and improved lumber quality.

The breeding for blister rust resistance is especially critical in zones of high-rust-hazards. These have been established in both the United States and Canada. In low and intermediate-rust-hazard zones the first filial generations of P. strobus plus trees, selected for the absence of disease symptoms and tested by artificial inoculation, will already possess satisfactory levels of resistance. The selection and incorporation of such plus trees into seed orchards is therefore very important.

In high-rust-hazard zones advanced filial generations of selected P. strobus trees, rust resistant interspecific hybrids of eastern white pine, or clones of blister rust resistant genotypes can be used. The development of such genotypes is feasible as demonstrated by accomplished research.

In Ontario, recurrent breeding of P. strobus resistant progenies has advanced to the second generation and, in some cases, to the third filial generation. We are close to the goal, and the genetic material possessing resistance offers also the possibility of recombination with other genotypes and the incorporation of different desired traits.

Some interspecific hybrids of eastern white pine, such as P. griffithii x strobus, P. peuce x strobus and P. monticola x strobus, have demonstrated acceptable levels of blister rust resistance. A more appropriate selection and combination of parent trees will likely result in families with high levels of blister rust resistance combined with other desirable characteristics, such as site adaptation, vigour of growth, and weevil resistance. These families of properly selected specific combiners can secure significant gains and result in stock tailored to specific needs and plantation technologies.

Clonal development, which has also been demonstrated as feasible, can advance these programs further, and result in even larger gains, as applied to specific needs and conditions. In Ontario, nursery hedges of more than twenty selections of blister rust resistant P. strobus and P. griffithii x strobus clones produced over 20,000 cuttings in this spring alone. These clones have been repeatedly tested for rooting ability and can now supply large numbers of rooted stock for testing on a variety of sites and in different plantation systems.

Weeviling can cause many problems, but as demonstrated in plantations, only the high-weevil-risk areas need special weevil resistant stock. In most areas trees in closed stands outgrow the weevil damage and develop into trees of satisfactory quality. The feasibility of selection for weevil resistance has been demonstrated in provenance collections and at times in interspecific hybrids. There is also a possibility of developing weevil resistant clones.

Provenances have been identified with lightly weeviled, fast growing trees, which can be used in high-weevil-risk areas. The provenance trials already established offer good information for the completion of this study and identification of best sources for a variety of sites.

Interspecific hybrids, especially of P. peuce x strobus and P. monticola x strobus, demonstrated at times weevil resistance coupled with other desired characteristics. This potential should be further explored, as in the case of breeding for blister rust, to secure large gains by appropriate selection of parental stock, families, and clones. Better selection criteria for weevil resistance are an important prerequisite of this work.

An improvement in growth intensity can be achieved, as demonstrated by provenance trials, progeny trials, interspecific hybridization and cloning.

Local provenances have seldom proven the best performers in trials. Southern Appalachian sources of P. strobus have shown superiority in northern latitudes and in many test locations. Other local sources have shown above average growth. There is a clear indication of the existence of several as yet not clearly identified local ecological races. Further studies and refinements of the provenance trials are needed to fully understand and explore this potential.

The plus tree progeny trials have demonstrated a large variation in the combining ability of maternal trees. The identification of best combiners offers genetic gains in seed orchard production and family selection. Thus the pursuit of this research is very important.

Some interspecific hybrids, especially P. griffithii x strobus in Ontario, and P. ayacahuite x strobus in northeastern states, demonstrated improved growth vigour. More research on interspecific hybrids is thus warranted, especially in combination with breeding for pest resistance, and for producing and selecting superior genotypes for cloning.

The improvement of lumber qualities, as indicated by stem and branching of trees, is feasible as well. Provenances with reduced branching and high volume production have been identified for use, as well as single trees with various types of branch angles. The heritabilities calculated for branch angle

and branch length were high (0.71 and 0.76, respectively) (Zsuffa 1975b) and the genetic gains in clonal propagation were predicted at more than 10%. The breeding for these traits appears feasible. However little work has been done with this objective. Furthermore, the potential for the improvement of interior wood qualities has remained almost completely unexplored. A study of the wood quality of 6 clones of hybrid white pine (P. griffithii x strobus) and 3 clones of eastern white pine (Balatinecz 1985) showed good possibility in this respect. Large clonal variation in bark thickness, heartwood percentage, moisture content, and specific gravity was observed. Both the eastern white pine and hybrid white pine samples (24 and 30 years of age respectively, average DBH 21-22 cm, average height 11-13 m) were of satisfactory quality.

It is safe to conclude, that there is a potential to achieve significant genetic gains in all of discussed improvement areas. The results and investments made into genetic improvement research and the continuation of programs will assure such success in the near future.

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THE INFLUENCE OF WILDLIFE ON EASTERN WHITE PINE

REGENERATION IN MIXED HARDWOOD-CONIFER FORESTS

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Abstract: Ground disturbances caused by wildlife, primarily gray squirrels digging and gathering acorns and hickory nuts, contribute to favorable seed bed preparation and protection from small mammal seed consumers for eastern white pine in mixed hardwood-conifer forests in the Northeast.

Observations in mixed conifer-hardwood forests throughout the Northeast seem to indicate that eastern white pine (Pinus strobus) seedlings and saplings occur in greater abundance under the canopy of large oaks (Quercus sp.) and hickories (Carya sp.) than elsewhere. Although there are a number of possible explanations for this occurrence, one possible factor is the activity of wildlife related to the use of mast crops (acorns and hickory nuts). Ground disturbances caused by the digging and food gathering activites of wildlife, such as gray squirrels (Sciurus carolinensis), may result in more white pine establishment on a mixed forest site than would occur if oaks, hickories, and wildlife were not present.

Many investigations have sought to confirm the role of gray squirrels in oak regeneration (Lange 1920, Seton 1921, Barnett 1976). Only recently have any studies been conducted on the amount or seasonal nature of digging activity by squirrels and the possibility that such surface disturbances may influence the establishment of conifer timber species occurring in a mixed stand---such as eastern white pine.

This paper sumarizes the findings of a series of studies that investigated the influence of wildlife on the establishment of eastern white pine in mixed forests. The topic will be approached by showing that: 1) gray squirrels disturb a significant amount of ground area; 2) this surface disturbance contributes to regeneration success; 3) there is interaction between abundant mast crops, gray squirrel ground disturbances, and pine seed consumers in terms of regeneration success; 4) regeneration density is greater near mast producing hardwoods. The implications of these findings for managing white pine will be discussed.

Ground Disturbances Caused by Squirrels

As reported by Alexander and Olson (1980) the ground activity of gray squirrels, red squirrels (Tamiasciurus hudsonicus), and eastern chipmunks (Tamias striatus) was routinely monitored in four mixed oak-hickory-white pine stands in southeastern New Hampshire from September 1977 through June 1979. Although this study sought to learn more about the ground disturbance activities of squirrels throughout the year, of particular interest was the seasonal digging activity of squirrels imediately before, during, and after white pine and red oak seed fall. Indirect observations of squirrel activity (i.e., counting squirrel digs and ground disturbances at frequent intervals) were the primary method methods of collecting data. A total of 908 "squirrel digs" and disturbances of surface litter were recorded during 74 observation periods.

Results of that study indicated that 84% of all ground disturbance activity occurred during the fall months (Fig. 1). An almost complete failure of the acorn and hickoy nut crop in the fall of 1978 did have a pronounced effect in gray squirrel populations and caused a significant decrease in digging activity that fall season.

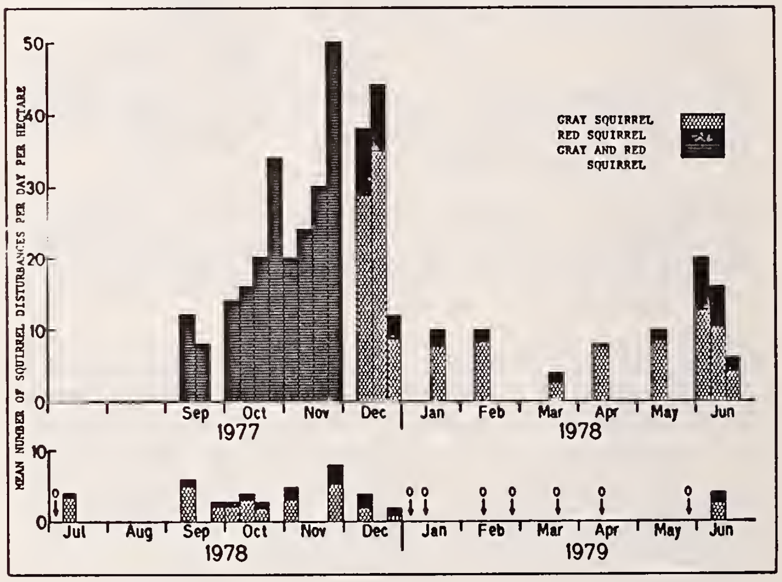

Figure 1 - Gray and red squirrel digging activity in four mixed conifer-hardwood stands in southeastern New Hampshire.

It was not until the first light snowfall in early December 1977 that an accurate determination could be made as to which species of squirrel was responsible for the different types of ground disturbances observed. Red squirrels characteristically moved leaves, litter, and some duff when foraging for food but normally did not dig into mineral soil. A red squirrel disturbance was thus more a result of a "searching" activity rather than digging. In contrast, a gray squirrels may make a similar "searching" disturbance but it would usually lead to some form of "digging" activity. Characteristically, gray squirrel "digs" were 4 to 18 cm deep (mean of 10.4 cm) into mineral soil and 5 to 9 cm in width (mean of 6.8 cm). Although it is known that eastern chipmunks

dig tunnels and burrows, no direct or indirect evidence of ground disturbances or digging related to food gathering or caching was recorded.

During the 22 months of squirrel digging observations, gray squirrels were responsible for 79% of all ground level disturbances (Fig. 1). At each of the mixed forest stands studied an average of 920 digs per month was recorded per hectare during the months of October through December. Based on a mean dig diameter of 6.8 cm, this amounts to approximately 54 m^2 of disturbed soil per hectare during the fall. It should be pointed out that this indication of the level of soil disturbance is conservative in that no acorn burying activity was recorded. Thus each observed "dig" was the result of two separate "digging" disturbances ---one when the acorn was buried and another when it was later recovered. It should also be stressed that depending on the number of mast producing hardwoods, the number of squirrels, and the abundance of the seed crop, the amount of fall digging activity at a particular site during a given year can vary greatly.

Impact of Seed Applications and Squirrel Exclosures

Alexander and Olson (1980) also reported on the results of a series of treatment plots in which first year white pine seedling response was evaluated using various oak-hickory and white pine seed applications under different levels of protection from seed gathering or disturbance activities by gray squirrels. The acorn-hickory nut treatments consisted of (1) the removal of all acorns and hickory nuts, (2) a normal or undisturbed amount of acorns/hickory nuts, and (3) an application of additional acorns and hickory nuts. White pine seed was added at the rate of 250 seeds/m^2. To prevent or reduce surface activity by gray squirrels, 2.5 cm wire mesh exclosures one meter square and 30 cm high were employed on one-half of the treatment plots.

Following the seed applications, most of the acorns, hickory nuts, and white pine seeds were removed or consumed by small mammals such as white-footed mice (Peromyscus leucopus) eastern chipmunks or red squirrels within seven days. On those treatment plots with an additional acorn-hickory nut application and no exclosures, considerable surface disturbance or digging was observed. Thus, the wire mesh exclosures effectively excluded gray squirrels but did not hinder acorn-hickory nut or pine seed consumption by smaller mammals which were able to penetrate the wire mesh or tunnel underneath the exclosure.

Overall, the use of exclosures which prevented gray squirrels from disturbing a site, resulted in a 43% decrease in first-year white pine seedling establishment compared to treatment plots with no exclosures. The application of acorn-hickory nuts resulted in a 65% increase in white pine seedling establishment. Chi-square analysis of the grouped white pine regeneration counts indicated a significant difference ($P < 0.01$) between treatment combinations (Table 1).

Table 1 - The number of first year white pine seedlings observed on 48 one-square meter plots in four mixed conifer-hardwood stands the summer after the addition of red oak acorns, hickory nuts, white pine seed, and the exclusion of gray squirrels. Each block represents 8 replications. Chi square = 11.78; df = 2; $P < 0.01$.

Acorn/hickory nut levels	Exclosure	Control	TOTALS
removal	28	23	51
normal	12	40	52
added	29	57	86
TOTALS	69	120	189

White Pine Regeneration Density in Relation to Hardwoods

To further analyze the influence of wildlife activity associated with the gathering/burying of upland hardwood mast crops (acorns and hickory nuts) on white pine establishment, six geographically separate mixed hardwood-conifer stands were studied in southern and central New Hampshire (Alexander 1980). At each study site, a combination of point plots, line transects, and nearest neighbor methods was used to survey the occurrence of white pine regeneration in a particular area in terms of density of white pine seedlings and the and distance to various seed sources. At each sample point the following information was recorded: (1) the density (number/10m^2) of all white pine seedlings and saplings; (2) the dbh and distance to the nearest mast producing northern red oak (Quercus rubra), white oak (Quercus alba), or shagbark hickory (Carya ovata); (3) the dbh and distance to the nearest northern hardwood such as American beech (Fagus grandifolia), yellow birch (Betula alleghaniensis), or sugar maple (Acer succarum); and (4) the distance to the nearest white pine seed source.

White pine regeneration density was found to be significantly higher ($P < 0.05$, $r^2 = .69$) when the site was in close proximity to a mast producing oak or hickory (Fig. 2). In comparison, there was no significant relationship of white pine regeneration density to the nearest seed producing northern hardwood. As shown in Figure 3, when the dbh of the nearest upland hardwood was large, white pine regeneration density was found to be significantly greater ($P < 0.05$, $r^2 = .63$). This appears to be logical since large diameter oaks and hickories produce more abundant seed crops per unit area than smaller sized trees. These sites most likely experience high levels of surface disturbance in the fall associated with the gathering of these heavy seed crops by wildlife.

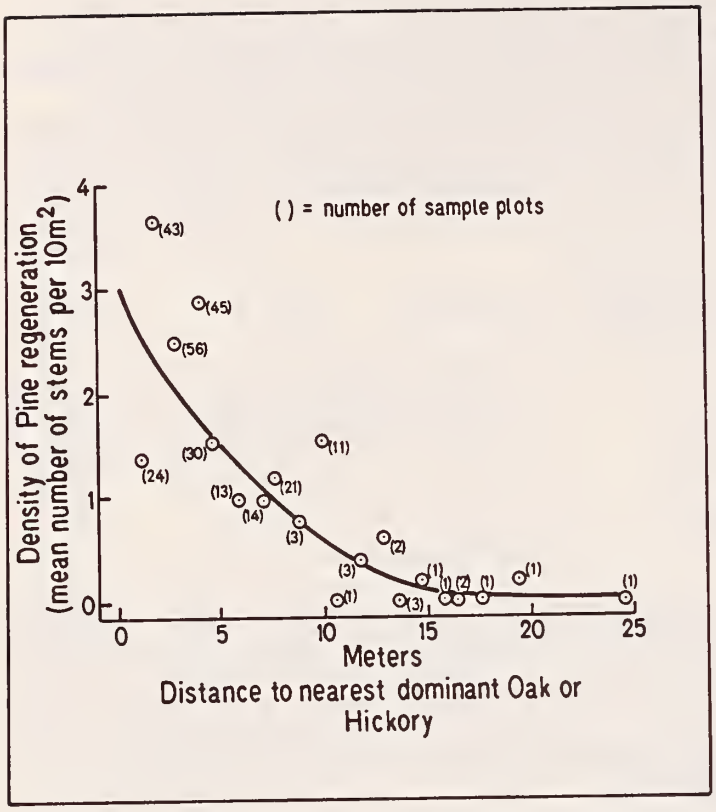

Figure 2 - The density of white pine seedlings and saplings in relation to the distance from the nearest mast producing oak or hickory.

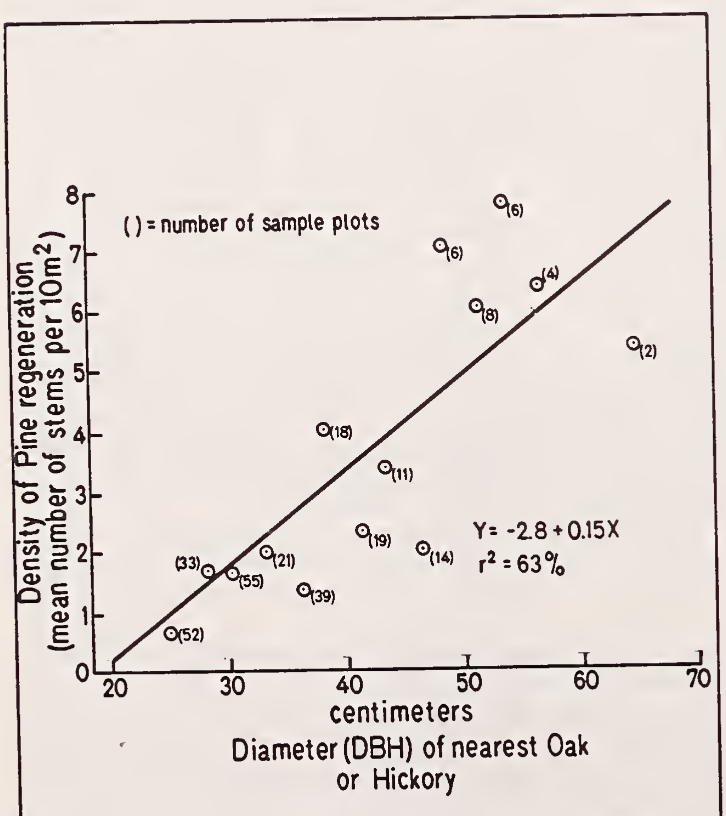

Figure 3 - The density of white pine seedlings and saplings in relation to the diameter (dbh) of the nearest mast producing oak or hickory.

It was expected that white pine regeneration density would be somewhat greater when in close proximity to a white pine seed source. However, our findings indicate that white pine seedling and sapling establishment in mixed stands was somewhat more successful at some distance from the probable white pine seed source. In several of the stands studied, understory white pine establishment successfully occurred at distances of over 100 meters from the nearest white pine seed source. This seems to indicate that the total amount of white pine seed produced is less critical to pine seedling establishment than is the mixture and proximity of white pine seed trees to oaks or hickories. In predominately upland hardwood stands, as few as one white pine seed tree and five mature, mast producing oaks or hickories per hectare can be sufficient to cause a desirable level of white pine seedling establishment.

Temporal Patterns in White Pine Regeneration

The ages of white pine seedlings and sapings occurring as an understory in these same six mixed hardwood-conifer stands were also determined (Alexander 1980). Of 596 seedlings and saplings sampled in 1978, an unexpectantly large portion were found to be 20 to 25 years of age (Fig. 4). This age class coincides with a reported period of excellent red oak and white pine seed crops and high populations of gray squirrels throughout the New England region during the mid 1950's. Although there is no way to conclusively establish that it was the acorn gathering and/or soil disturbance activity of gray squirrels during this time period that accounts for the abnormally large 20-25 year age class of understory white pine saplings, it does seem likely that there was some form of region-wide "disturbance" which influenced the occurrence of successful white pine regeneration in mixed upland hardwood - conifer stands in central New England.

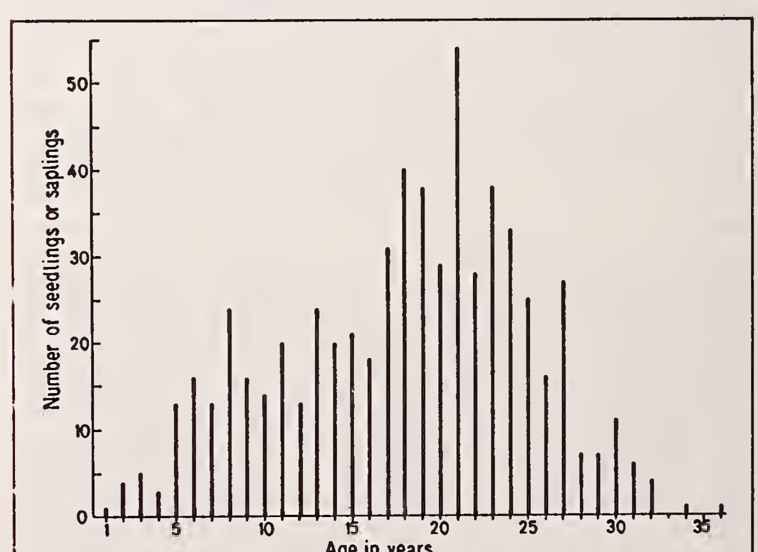

Figure 4 - The age distribution of 596 white pine seedlings and saplings in six, geographically seperate, mixed hardwood-conifer stands in southern and central New Hampshire in 1978.

White Pine Seed Consumers

Many studies have investigated the deleterious effect of wildlife activity on forest stand regeneration or development. A variety of small mammals in Northeastern forests feed to some degree on coniferous seeds (Abbott 1962, Pank 1974, and Smith and Aldous 1947). Radvanyi (1973) lists white-footed mice, red-backed voles (Clethrionomys gapperi), chipmunks, and to some extent shrews (Sorex sp. or Blarina brevicauda) as some of the more important species. Research by Hamilton (1941) concluded that under natural conditions, adult deer mice (Peromyscus maniculatus), jumping mice (Napaezapus insignis), and red-backed voles eat food equivalent to 30% of their daily weight or about six grams, while short-tailed shrews eat about 50% of their weight daily or about 20 grams. Based on Lovejoy's (1975) population estimates in mixed hardwood-conifer forests in the Northeast, a population of 60 to 100 seed eating mammals per hectare could collectively consume up to 750 grams of seed daily. A series of laboratory and field experiments by Abbott (1961) on the consumption of white pine seed by white-footed mice and red-backed voles demonstrated that the two species were capable of removing virtually all naturally produced or artificially seeded white pine seed which they were able to find. Studies by Graber (1969) reinforced this point that conifer seed losses to small mammals could total 82% but were measurabley less when the seed was covered with soil.

Although certainly not the only factor, it seems evident that the fall digging activity of gray squirrels in mixed forests may be a beneficial influence on the amount of white pine seedling establishment that occurs in mixed conifer-hardwood stands. Since gray squirrels are not consumers of white pine seed (Smith and Follmer 1972, Short 1976), a major portion of their fall activity concerns the gathering and burying of acorns and hickory nuts. It is digging and ground level disturbance activity that inadvertently covers white pine seed, thus affording it protection from white pine seed consuming small mammals as well as providing a more favorable mineral soil seedbed for seed germination and seedling survival. Neither the amount of pine seed produced by the seed tree nor the activity of seed consumers may be as important as the role of other wildlife species in determining what happens to the seed once it falls to the ground.

Even though our studies have primarily focused on the digging activities of gray squirrels, it is widely known that other wildlife species such as white-tailed deer (Odocoileus virginianus), striped skunk (Mephitis mephitis), wild boar (Sus scrofa), black bear (Ursus americanus), wild turkey (Meleagris gallopavo), and bob-white quail (Colinus virginianus) all contribute to ground level disturbances. Even in areas with few gray squirrels, if the activities of other wildlife species were to coincide with a good seed year for white pine, pine seed germination and seedling establishment would be enhanced.

Implications for White Pine Management

Historically, most forest managers in the Northeast have felt inclined to grow or manage for white pine in predominately pure and homogeneous stands. The abundance of abandoned fields and pastures during the early part of this century which became relatively even-aged, monotypic white pine stands also led many to believe that this was the norm for the so-called "natural" establishment of white pine. Only recently has it been stressed that there are increasingly fewer sites in the Northeast where white pine will successfully regenerate to pure stands (Lancaster and Leak 1978).

Despite age-old problems of site preparation, overstocking, hardwood competition, and severe white pine weevil problems when white pine grows in full sunlight sites, there are a number of forest managers who still feel that initially trying to grow monotypic, even-aged stands of white pine in open fields is the best approach. Past efforts to regenerate white pine on so-called open sites usually involved burned-over areas or brushlands that had been previously clearcut. In most instances, hardwood sprouts, briars, shrubs, and ferns were all too prevalent, making the site unfavorable for white pine seedling establishment or growth. Intensive site preparation by mechanical or chemical methods was often recommended or required (McQuilken 1959). However, since considerable effort and expense were involved in the site preparation, few forest managers were willing to rely the vagaries of natural seeding for regeneration. Thus, direct artificial seeding or planting nursery grown seedlings has become the typical practice following site preparation. Despite these efforts, regeneration success is usually limited (Lancaster and Leak 1978). Along with a number of other factors, wildlife was often considered "part of the problem."

Direct versus "Natural" Seeding

During the past two decades, much research has focused on developing direct seeding technology to overcome the unreliability of natural seed crops and the uncertainty of natural regeneration. Although direct seeding for conifers has been somewhat successful in the upper Midwest and in the South, it has not been all that effective in the Northeast (Abbott 1973).

Problems associated with direct seeding in the Northeast include the nature of the climate, soils, vegetation, topography, and seed consumption by wildlife. On mechanically prepared sites, frost heaving of seedlings exposed on predominately mineral soil beds may exceed 75% during the first winter (Graber 1971). In New England there are limits on the use of mechanical equipment since many sites are stony, interspersed with rock outcrops, or of steep and broken topography. The woody growth of shrubs, saplings, and pole trees can make equipment or cultural operations all the more difficult. In addition, there is as yet no suitable method of preventing excessive loss of pine seed at the direct seeding site by small mammals or birds (Abbott 1961). Studies by Graber

(1973) indicate that even the use of a protective coating such as ENDRIN-ARASAN did not give adequate protection under Northeastern conditions unless the seed was also covered with soil.

Despite the many problems associated with direct seed methodology, almost all direct seedling studies have pointed out the need for a mineral soil seed bed and the advantages of partial shading to provide a microclimate favorable for germination and seedling survival (Abbott 1961, Graber 1969, Hocker 1961, Smith 1951). As previously suggested, once white pine seed reaches the ground, the fate of the seed in terms of concealment or burying, is perhaps more important to seedling establishment on that site than the total amount of seed naturally produced or applied.

Mixed and Uneven-age Forest Management

Mixed forest management employing more than one species and age class may be particularly appropriate for Northeastern forests. There is now sufficient evidence that wildlife associated with mature mast producing upland hardwoods may enhance the regeneration of white pine in the understory of conifers may increase the value of hardwood species such as red oak (Kelty 1984). Furthermore, the vigor of hardwood advanced regeneration in pine stands is well appreciated by Northeastern foresters. Management of each species will be aided by an alternation of species occurring within the same stand, although this type of alternation will necessitate the management of more than one age class in each stand.

So-called uneven-age management is often avoided because it is complicated from both a mensurational and a financial analysis point of view (Hann and Bare 1979). Because of the mathematical difficulties and a lack of data to develop appropriate yield tables, management of these complicated stand structures has been left in a form that many consider to be "unscientific". Experienced foresters have been able to make the numerous mid-rotation corrections that mixed forest management requires, but a rigorous body of knowledge transmittable to new foresters has yet to be developed.

Complex forest stand structures, although difficult to study, actually provide the forester with far more management flexibility. Harvesting can take advantage of several markets simultaneously. Also, thinning in one species and age class can be combined with a final harvest for another species or age class. No one insect or disease is likely to destroy a stand because the other species might take advantage of increased growing space. This is especially important considering the impact of pine weevil and gypsy moth on New England forests. The shade of the hardwoods will actually reduce the pine weevil problem in a stand and the shade of a white pine understory will reduce the incidence of epicormic branching in the hardwood species.

Using the natural regeneration capabilities of the species instead of forcing a system against nature will result in lower costs at the front end of each rotation. This type of management is labor intensive (on the part of the forester rather than capital intensive. This should result in lower overall discounted management costs. In addition these stands will likely have increased appeal to the majority of private, non-industrial forest landowners in the Northeast who are far more interested in aesthetics and wildlife than timber management (Alexander 1985). Finally, there are significant benefits to wildlife associated with maximizing mast and browse production in a mixed forest ecosystem.

The Need for a Broader Ecological Approach to White Pine Management

Most studies and reports on the forest biomass in the Northeast indicate that the dominant presettlement forests were mixed hardwood-conifer stands (Bromley 1935, Marsh 1865, Nichols 1935). Even though cultural activities, including land clearing, agriculture, and lumbering greatly altered the species composition and structure of the original forests, the hardwood-conifer forest continues to be the dominant forest type in the Northeast (Oosting 1956). Although past and present timber management practices may be leading to a managed succession which results in a less complex and less heterogeneous forest, the ecological interactions that influence and maintain these mixed forests still occur.

The combined findings of our report illustrate the need for a greater understanding of the mixed forest ecosystem. There are a whole host of naturally occurring processes which involve interaction between wildlife, plants, and environmental conditions that should be recognized and incorporated into a more ecologically integrated system of timber management. The findings of this report dealing with the influence of gray squirrels and red oaks on white pine establishment in mixed forests probably represent only a small portion of the complete story.

The "bottom line" would seem to be that silvicultural practices relating to the establishment and growth of eastern white pine on mixed forest sites in the Northeast will be more effective and less costly if naturally occurring influences and interactions are considered. Rather than trying to modify or control ecological influences, we should work with them. Timber management practices will not be efficient if they require the importation of labor and machinery or time and expense to accomplish that which can be achieved through naturally occurring processes.

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GROWTH ESTIMATES IN NATURAL WHITE PINE STANDS OVER TWO DECADES

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The mortality and growth in natural white pine stands are examined based on 50 plots in New Hampshire. Estimates include basal area per acre, basal area increment, and board and cubic foot volumes. White pine is a productive timber species, especially in board foot volume, and growth of white pine is sustained at high levels to ages of 80 to 100 years.

Critical to forest management is information on growth and yield. Although adequate yield information is available, extensive stand growth information does not seem to be available for eastern white pine (Soloman, 1977). The purpose of this paper is to present the growth rates and growth characteristics of natural white pine stands in New Hampshire.

In 1960 roughly 70 semi-permanent growth plots were established in New Hampshire by Peter Allen under the Hatch 149 project entitled "Effects of Site and Stocking on the Growth of Eastern White Pine". These stands were even-aged (overstory varying no more than 10 years in age), contained at least 80% of the overstory basal area in white pine, and had no major disturbance over the previous 15 years. The plots were selected to cover a fairly wide range of ages and site indices (Figs. 1 and 2).

These plots were periodically remeasured for tree heights, diameters, and crown classes. Of the original plots, 50 survived with no major disturbance since 1960. A 20 year data set (1960-1980) was established and used for the growth figures in this paper.

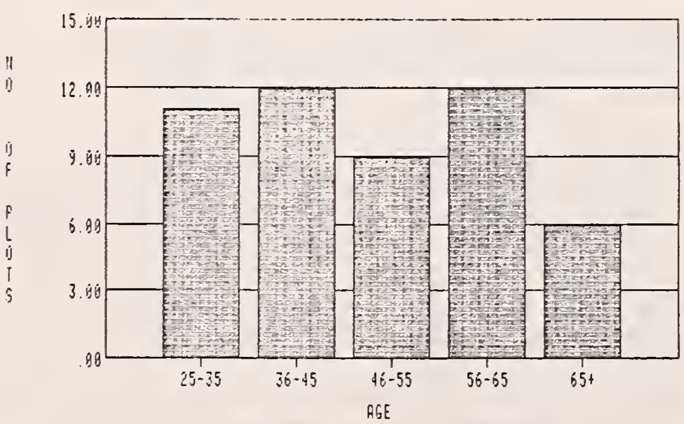

Figure 1. Age classes at establishment

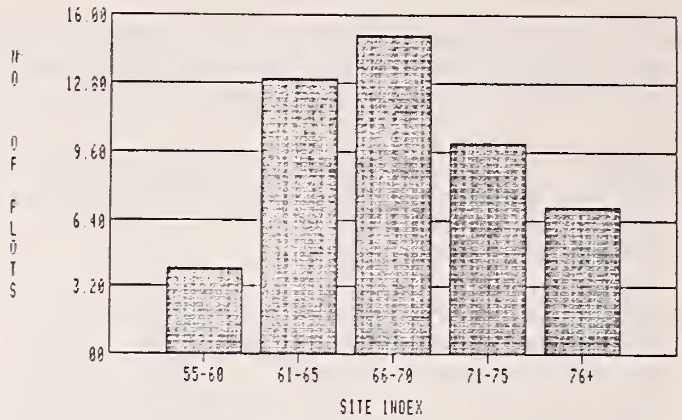

Figure 2. Site Indices at establishment

One important factor to keep in mind is that these plots are natural stands. Natural white pine tends to grow in dense, overstocked stands. This overstocked condition can be seen when the plots are graphed on the White Pine Stocking Guide developed by Philbrook et.al. (1973). As can be seen in Figure 3, all of the plots are above the B-line, with a good portion above the A-line. This overstocked condition causes mortality levels to play a significant role in growth figures. According to Horton and Bedell (1960), "in overstocked stands mortality may equal or for short periods even exceed growth, in which case the net current annual increment would be small or even negative". This was the case for net basal area growth on our plots (Fig. 4). Because of this pattern, our growth figures will be in gross growth terms.

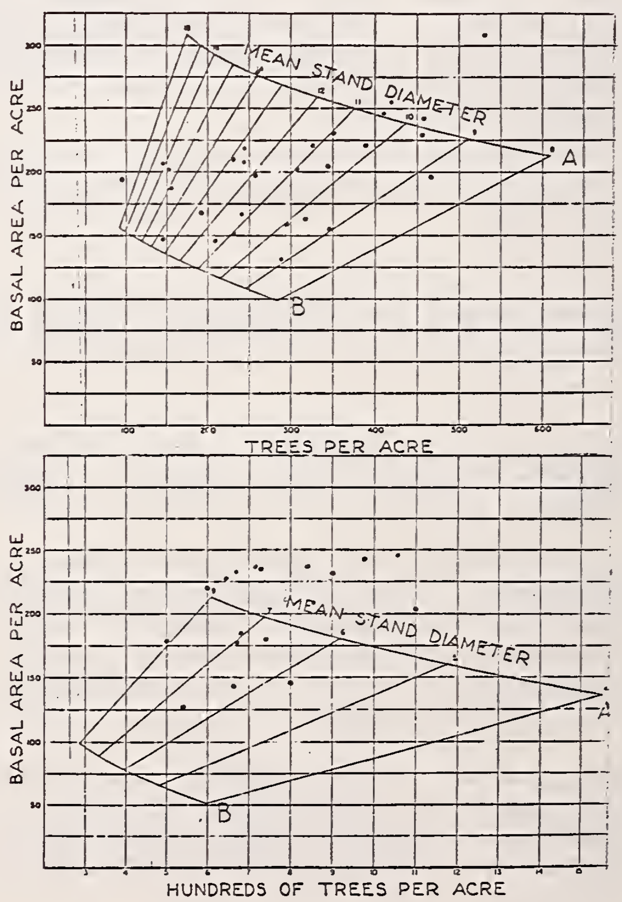

Figure 3. Plots graphed on the White Pine Stocking Guide

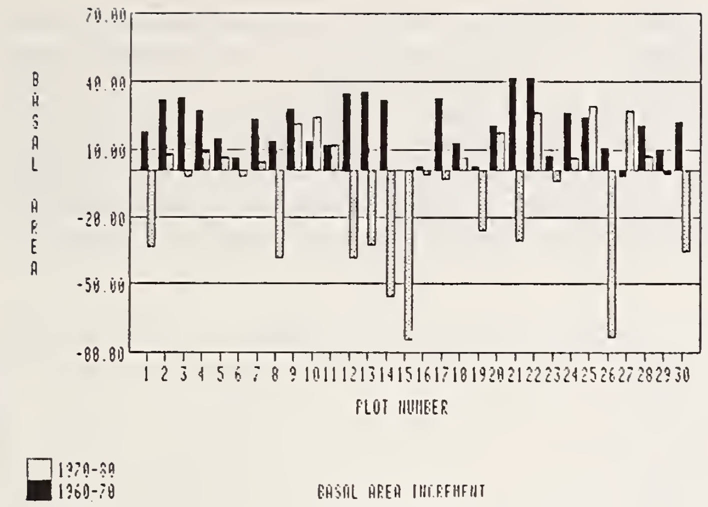

Figure 4. Net Basal Area Growth

Smithers (1954) states that gross basal area increment decreases with age. We also found this to be true, as shown in Figure 5. This graph gives the 20 year basal area increment over plot establishment age, along with the regression line. The regression line shows a slowing of basal area growth as the stands age, which is consistant with Smithers and also Frothingham (1914), who found that the growth of white pine reaches its maximum early in life, and then slowly decreases.

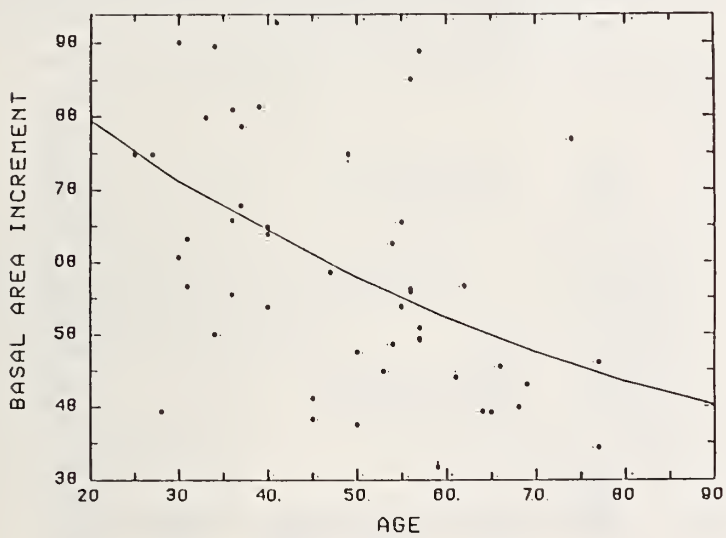

Figure 5. 20 Year Basal Area Increment

After establishing the basal area growth pattern for the 20 year period, the next step was to determine whether the growth rate changed significantly over that period. We divided the data set into two periods. Because of the remeasurement schedule, the first period consisted of 9 years, the second period 11 years. So all figures were put on an average annual basis for comparison. A paired t-test (Fig. 6) revealed a significant difference between the two periods. A graph of the increment equations for both periods (Fig. 7) shows a parallel slope, but a slight difference in elevation for the two lines. Since age proved significant in basal area increment, the slight drop in elevation might be attributed to the difference in ages of the two periods.

```
PERIOD 1   N =  50    MEAN =      3.8298    ST.DEV. =      1.04
PERIOD 2   N =  50    MEAN =      3.0175    ST.DEV. =      1.08

APPROX. DEGREES OF FREEDOM =  97

A 95.00  PERCENT C.I. FOR MU1-MU2 IS (     0.3915.     1.2331)

TEST OF MU1 = MU2 VS. MU1 N.E. MU2
T =  3.88
THE TEST IS SIGNIFICANT AT  0.0002
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Figure 6. Paired t-test for the two periods

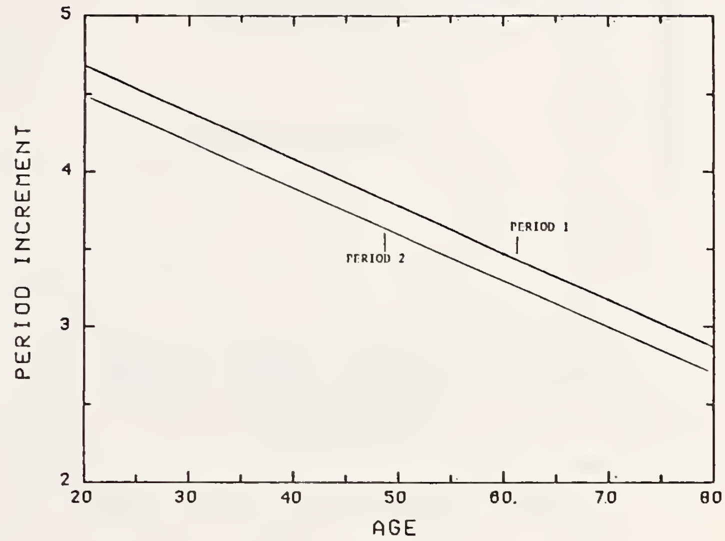

Figure 7. Regression lines for the two periods

This declining growth rate of basal area for white pine should not be a discouragement to management of the species. These curves represent a normal progression toward senesence, consistent with normal tree stand growth theory (Avery, 1975). Also, one look at the numbers will reveal that, although declining, the growth being accumilated by white pine is still considerable. White pine is a long-lived tree (Fowells, 1965), and a high level of mean annual growth can be maintained even in stands approaching 90 years of age (Barrett et. al., 1976)

Volume growth figures also show white pine to be a high yielding tree. Figure 8 shows current and mean annual board foot growth curves derived by Barrett et. al. (1976). At 90 years of age, the two curves have not yet crossed, which is consistent with Ardenne (1950) who suggests rotations of 100-150 years, based on maximum growth.

The regression equation for board foot volume based on plot establishment figures is in Figure 9. The graph shows an expected high correlation with age. The slope of this line demonstrates a very robust volume per acre. In fact, the 50 plots averaged a 20 year increment of 19,856 board feet (International 1/4 inch rule) per acre, or 993 board feet per acre per year for 20 years. This figure is consistent with Hawley's (1930) findings of 921 board feet per acre per year for 65 year old stands in New Hampshire, and even Della-Bianca's (1970) figure of 1,141 board feet per acre per year for 58 year old stands in North Carolina.

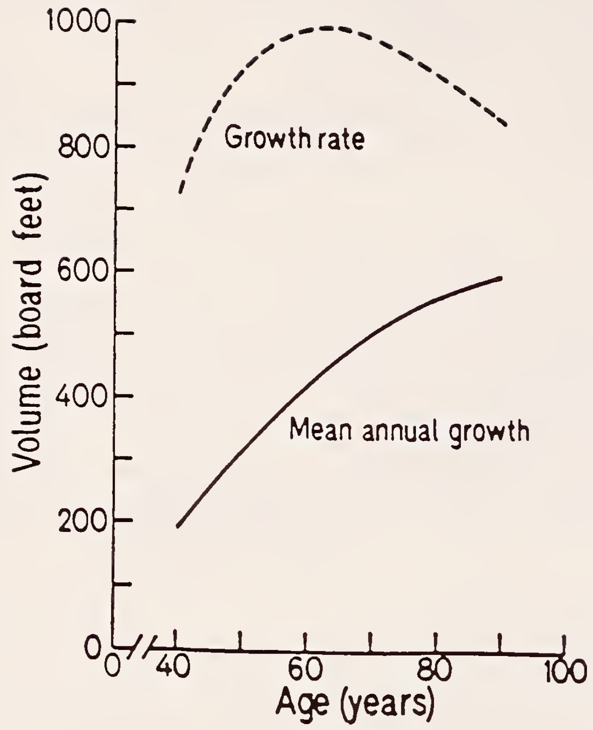

Figure 8. Board Foot Growth Curves

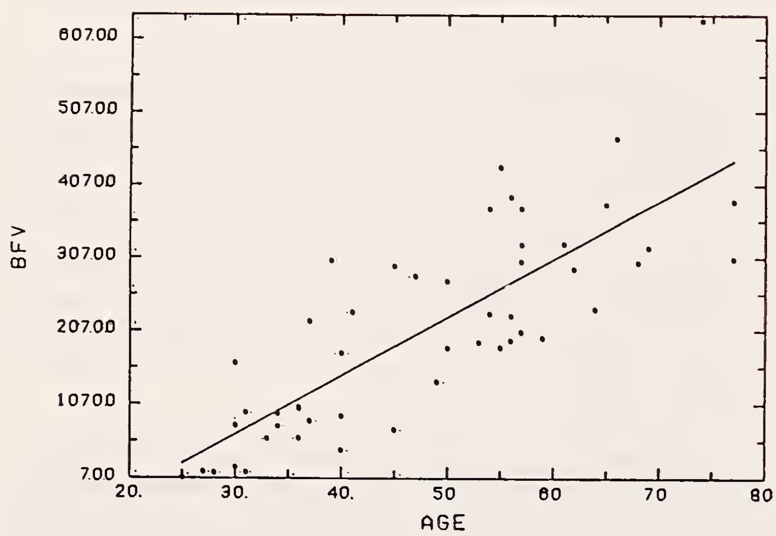

Figure 9. Board Foot Volume Regression Line

The cubic foot volume regression (Fig. 10) shows the same relationship as the board foot equation. The slope is not as large, mainly because with board foot measure, the older stands show a larger increase due to the movement into larger diameter classes, which become merchantable, and therefore measurable, with age. Figure 11 gives the current and mean annual cubic foot growth curve derived by Barrett et.al. (1976). Although these two curves do intersect at a relatively young age, the sustained growth extends over a long period of time. Our plots averaged 1,916.8 cubic feet per acre growth over the 20 year period, or 95.8 cubic feet per acre per year. The steep drop in current annual growth in Figure 11 can be explained by mortality, since according to Smithers (1954), "little cubic foot mortality is evident up to 30 years of age, but thereafter it increases rapidly with age until about 70 years of age, after which it levels off". Smithers' time frame corresponds almost exactly with the steep decline in the curve in Figure 11.

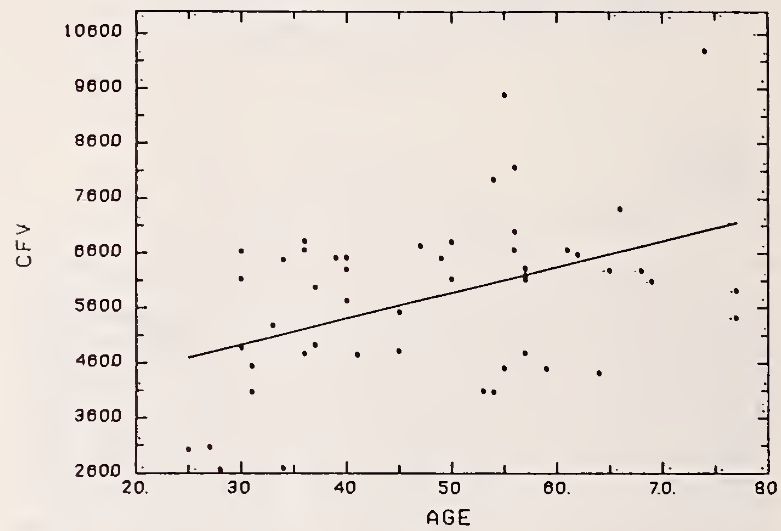

Figure 10. Cubic Foot Volume Regression Line

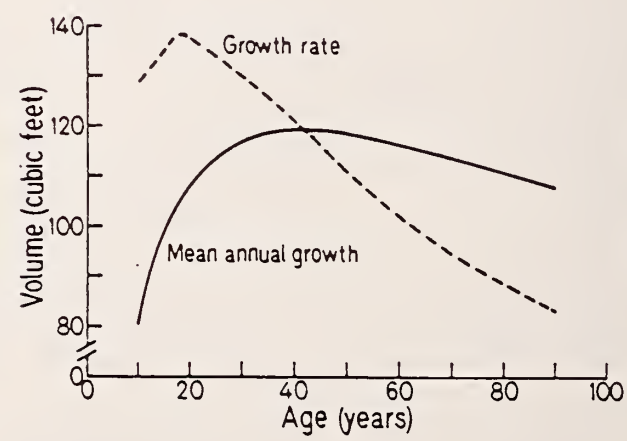

Figure 11. Cubic Foot Growth Curves

The effect of mortality on natural white pine stands has already been mentioned. These high levels of mortality would be expected of overstocked natural stands. According to Smithers (1954), "in natural stands, basal area increment still continues in the stand. This increment, however, is balanced by mortality so that the net basal area remains relatively constant at ages greater than 60 years". This statement is based on the graph in Figure 12.

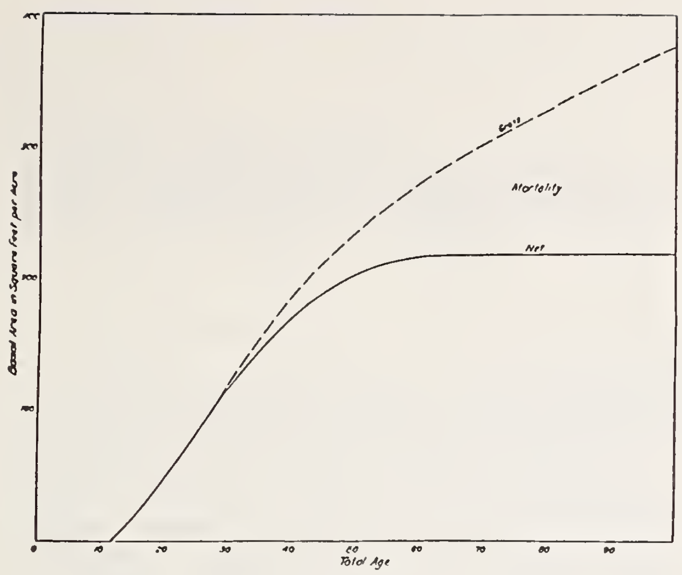

Figure 12. Effect of mortality on Growth.

The relationship of age on trees per acre is shown in Figure 13. A curve this steep would be expected of stands that were as overstocked as these were. Figure 14 shows the distribution of the number of trees on the plots when divided into crown classes. And Figure 15 shows the percentage of those numbers of trees that died by crown class. The distribution is what would be expected from natural competition, the suppressed category with high levels of mortality, with progressively less mortality as we move up in dominance.

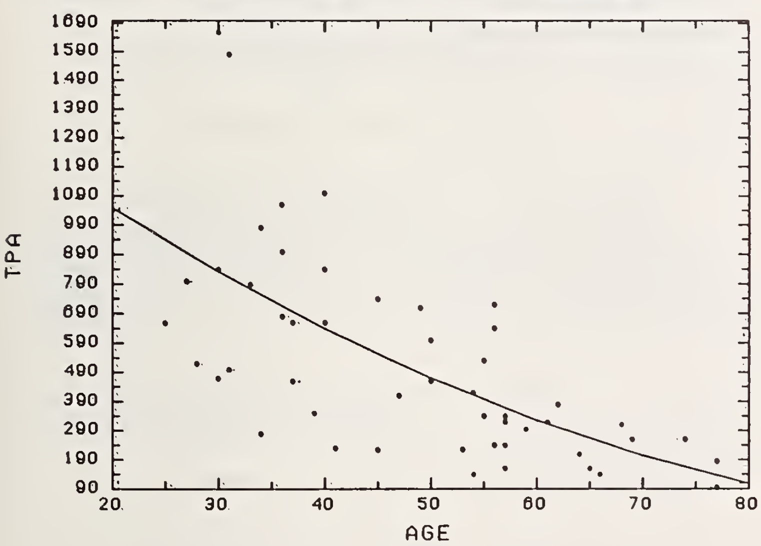

Figure 13. Trees per Acre Regression Line

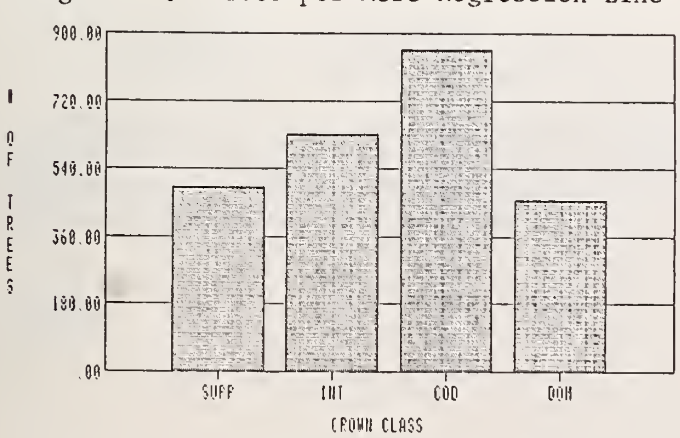

Figure 14. Number of trees by crown class

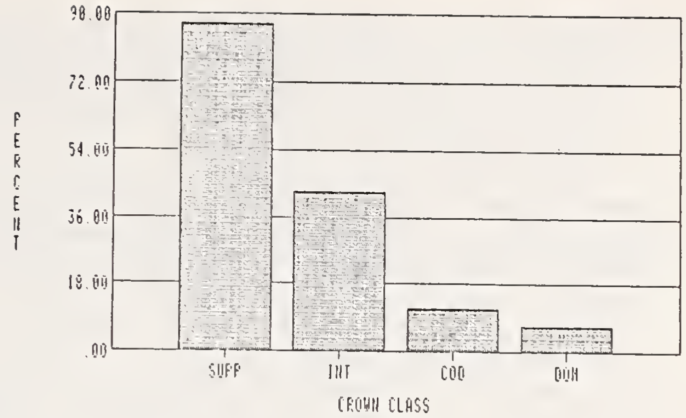

Figure 15. Percent mortality by crown class

What we have tried to present in this paper are the growth rates and characteristics of eastern white pine. The basal area, board and cubic foot volume increment figures presented demonstrate white pine to have consistant and robust growth in New Hampshire. The reader must bear in mind that these figures are for natural stands, and that the volume figures represent average numbers for plots with a fairly wide distribution of age and site indices.

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STOCKING OF WHITE PINE

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There is a difference of opinion on whether white pine should be grown at high density or low density. The high-density approach consists of little or no thinning until the stand reaches 6-8 inches dbh, maintenance of 90-100 square feet basal area per acre in poletimber stands and 120-140 square feet in sawtimber, and some selective pruning. This approach should result in maximum board-foot volumes of medium quality pine, low investments, and minimal hardwood understory development. Under the low-density approach, thinning may begin at mean diameters of 4-6 inches. Basal areas may be 30-40 square feet in poletimber and 60-80 square feet in sawtimber. A heavy commitment to pruning and hardwood understory control is required. This approach apparently will produce lower volumes per acre per year (up to 30 percent lower), but results in earlier returns and higher log quality (pruned lower and red-knotted uppers). The choice between the two approaches depends heavily upon prospective markets, prices, and costs.

Because of preference or given stand conditions, some foresters grow white pine at high stand densities, and some at low stand densities. The pros and cons of each approach follow.

Stand density affects at least three major types of stand response:

1. Growth in cubic feet and board feet.

2. Quality--number and size of live and dead branches, weevil damage and recovery.

3. Understory development--which influences subsequent regeneration.

The discussion of stand responses concerns essentially pure white pine stands (75 percent pine or more). Density recommendations for pine-hardwood stands will be lower.

Growth

A standard stocking guide for white pine was developed by Philbrook and others (1973) and reproduced in a northeastern white pine silvicultural guide (Fig. 1) (Lancaster and Leak 1978). The B-line in this guide was recommended as minimum stocking for maximum growth per acre. However, the guide was based on crown dimensions or tree areas, and needs to be checked against actual growth measurements.

Schlaegal (1971) showed that board-foot response of thinned sawtimber white pine was best at a residual basal area of 140 square feet--the highest basal area tested (Table 1). This corresponds closely to the 145 square feet recommended in the Philbrook stocking guide. Growth at 140 square feet was 38 percent greater than growth at 80 square feet (Table 2). The work by Barrett and Goldsmith (1973) generally indicates best growth (cf and bf) at high densities--around 200 square feet basal area or more. However, a 45-year-old white pine plantation that had been thinned several times so that crowns were well developed, showed no drop in growth down to 100 square feet basal area, and very little decline down to 80 square feet. The B-line basal area for this 10-11 inch stand was 120 square feet (Leak 1982).

Some data are available on the effects of low density. Plantation studies clearly show that the early advantage in board-foot growth is attributable to wide initial spacing. At 35 years, board-foot volumes of plantations spaced at 6 x 6 feet are only 70 percent of those spaced at 12 x 12 feet (Vimmerstedt 1962). However, a plantation spaced at 12 x 12 feet supports 100 to 150 square feet of basal area between ages 25 to 35--densities that are not inconsistent with the residual densities recommended above.

Hunt and Mader (1970) studied plots thinned to 30, 105, and 166 (unthinned) square feet basal area per acre in 22-year-old white pine plantations averaging 6 to 7 inches dbh. B-line would be 80 to 90 square feet according to the white pine stocking guide. Dbh growth over 5 years roughly doubled with each decrease in density level. But basal area growth was roughly a third more under 105 square feet density as compared to 30 square feet. The authors emphasized the possibility of early heavy thinning to rapidly produce sawlogs with clear (pruned) buttlogs and sound-knotted upper logs. This approach also has been advocated by Smith (1977).

Although based on a few small plots, results from seven thinnings over an 80 year period in the Biltmore plantations are interesting (Della-Bianca 1981). At age 20, a thinned plot (site index 71) was reduced to less than 40 square feet while a control plot (site index 75) was left at 80 square feet.

At age 26, the thinned plot was reduced to 60 square feet while the control remained at over 120 square feet. Five more thinnings were applied with residual basal areas ranging from about 90 to 125 square feet; during this same period, basal areas on the unthinned control increased from about 160 to 230 square feet per acre. Board-foot volumes showed an early advantage (up to about age 35) on the thinned plot. But over the 80-year period, there was a little more (4 mbf) total board-foot production on the unthinned plot. Average diameter on the thinned and unmthinned plots was 17.0 and 13.6 inches, respectively; however, the thinned plot had only 8 more large trees (>16.6 inches) per acre than the unthinned. In summary, the Biltmore thinning regime began as low density, and then approached roughly the C-line densities proposed in the white pine stocking chart. Board-foot yields were slightly reduced by thinning, though there was some advantage in terms of larger trees and probably improved stem form.

It is useful perhaps, to look at density recommendations for red pine. Buckman's classic work indicated that board-foot growth of red pine over an age range from 50 to 160 years was best at 120 square feet of basal area or more (Buckman 1962). Lundgren agrees (1983). Benzie (1977) suggests 90 square feet residual in poletimber red pine; and 120 square feet or more in sawtimber. The stocking chart for red pine recommends 60 to 100 square feet for mean diameters of 5 to 16 inches.

On the basis of board-foot growth, the available information indicates that stand densities of 90 to 100 square feet in poletimber and 120 to 140 square feet or more in sawtimber are in the ballpark. In stands thinned several times to maintain wide crowns, it is possible to drop these recommendations by up to 20 square feet. This means that the white pine stocking guide up to 8 inches dbh should be raised, and perhaps lowered a little in the large sizes. However, the work at Biltmore raises the question of whether intermediate cuts will have much effect on the long-term production of board-foot volume. But we still need to look at quality and understory development.

Quality

In the Northeast, white pine weevil is the most serious threat to bole quality because it causes forks and crooks. It is generally recognized that weevil damage is greatly reduced by growing stands under a partial overstory (to reduce weevil attack) or by growing stands at high densities (e.g. 150 square feet) to encourage stem recovery until they reach about 4 to 6 inches dbh. High density also results in some natural pruning as well as small branches that are readily pruned by mechanical methods.

When stands approach poletimber size, there seems to be two general schools of thought. The low-density group says to start early (4 to 6 inches dbh or 30 to 40 feet tall), thin heavily, prune many trees, return frequently, and maintain as much live crown as possible. The aim is to produce sawtimber trees as rapidly as possible, with clear (pruned) lower boles and red-knotted upper logs. This approach could have some economic advantage in terms of shorter time frames and added log quality. But volume losses apparently will occur if density is reduced below the 90 to 140 square feet suggested earlier.

The high-density advocates lean toward entering late for a commercial thinning (at about 6 to 8 inches dbh), some selective pruning, moderate thinning at longer intervals, and closed stands to encourage small limbs and some natural pruning on lower and upper logs. This approach should produce a lot of medium-quality volume at low investment--possibly a good option where markets do not pay much premium for quality. Another advantage of the high-density approach related to understory development . . .

Understory

Pine regeneration depends partly on the prevention of excessive competition from hardwoods. Low-density management greatly increases the buildup of a hardwood understory that must be dealt with (chemically, mechanically, or with fire) during the regeneration period. High-density management provides some natural control over the hardwood understory, though it may not eliminate the need for some hardwood control. My estimate is that sawtimber stands managed at densities much below 100 to 120 square feet will develop very competitive hardwood understories, especially on sites that are not sandy or gravelly outwash.

Summary

Can we reach any consensus on white pine stocking? If the objective is to grow high volumes of medium-quality pine at low investment, I would suggest high density, or some residual overstory, until 6 to 8 inches mean dbh with no cutting or only light cutting to avoid excessive overtopping by hardwoods. From that point on, I would suggest 90 to 100 square feet residual basal area in poletimber stands and at least 120 to 140 square feet or more in sawtimber.

The other option is the low-density route; basal areas of 30 to 40 square feet in poletimber and 60 to 80 square feet in sawtimber. A strong commitment to pruning and control of understory hardwoods is required. Losses in volume production (which tentatively might approach 30 to 40 percent) will have to be compensated for by rapid diameter growth, early timber returns, and premium prices for clear pruned logs and red-knotted uppers.

Recommendations such as these are tempered by the real world. Armed with the knowledge that I wanted to leave 120 to 140 square feet, I marked a sawtimber stand a couple of years ago. It was a small tract; the logger wanted a minimum number of truckloads; I wanted a certain dollar return; the stand contained many rough old veterans plus some good small sawtimber; it was a hardwood site; the general area contained deer, grouse, and woodcock, but this stand was devoid of understory cover and wildlife activity, etc. I left about 80 square feet.

The primary research need with regard to white pine stocking is long-term growth, yield, and quality of managed stands related to stocking level or thinning intensity. Two related needs are: (1) the optimum type and degree of silvicultural control to minimize damage from the weevil, and (2) control of stem quality through high initial density, efficient pruning techniques, or a combination of approaches.

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Table 1.--Summary of some optimum residual basal areas for growth of white pine stands.

Source	Species	Age or diameter	Unit	Optimum BA	B-line
				ft^2	ft^2
Schlaegel 1971	WP	app. 14 in.	bf	140	145
Barrett and Goldsmith	WP	50 years	bf	200±	app. 110
Leak 1982	WP	10-11 in.	ft^2	100	120-125
Buckman 1962	RP	all ages	bf	120+	60-110
Hunt and Mader 1970	WP	22 yrs., 6-7 in.	ft^2	105	80-90

Table 2.--Annual growth over 15 years related to residual basal area for an 80-year-old stand in the Lake States (Schlaegel 1971).

Residual basal area	Annual growth	
	Basal area	Board feet
80	2.56	605
100	2.95	707
120	3.07	793
140	3.15	835

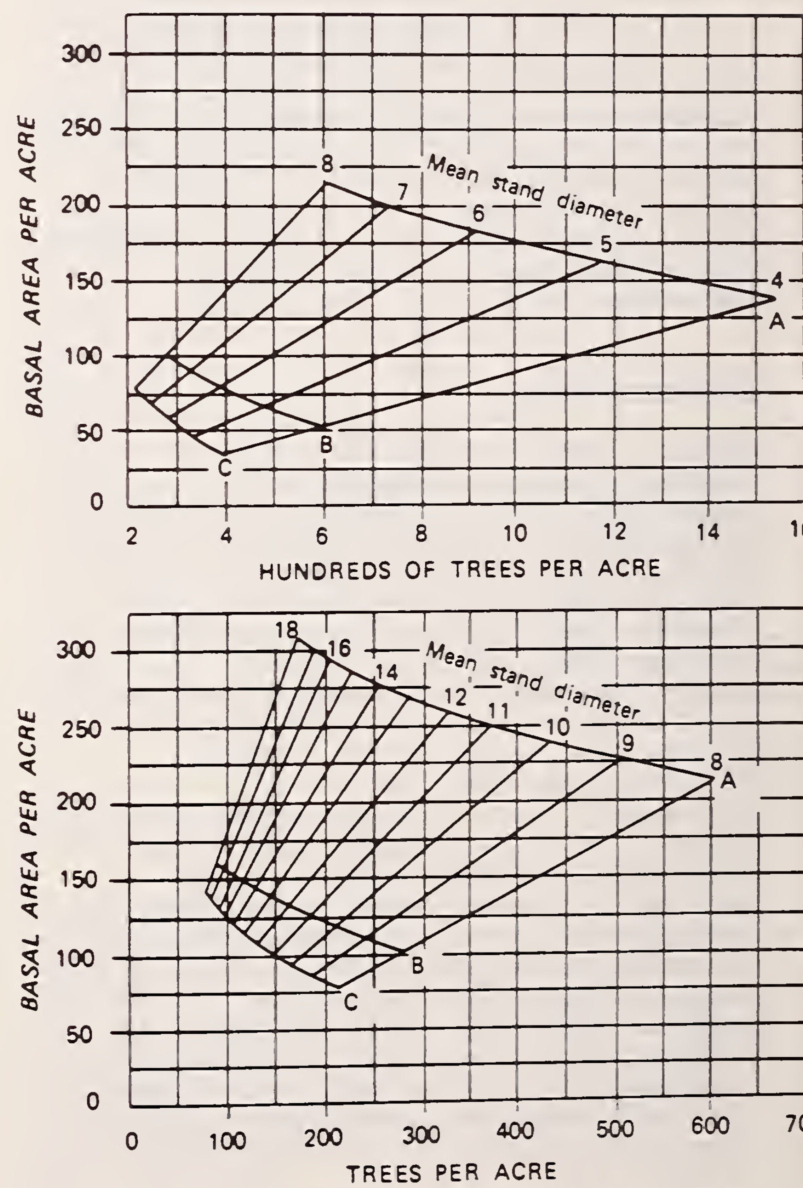

Fig. 1. Stocking chart for nearly pure even-aged white pine stands. (Philbrook et al. 1973)

CONVERTING TO WHITE PINE AND PLANTATION MANAGEMENT

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Sites suitable for conversion to white pine are droughty tills and glacial outwash supporting scrub oak, gray birch, and other hardwoods such as oaks and poplars, and/or pitch pine. Such sites can be planted with little or no hardwood control, if timing is correct. In order to improve the success of establishment, there is a need for superior stock having the capability to get off at a fast start the first year of planting.

Outside of hardwood control, cultural treatments such as thinning probably should take place when the stand is 30-35 years of age, depending on the incidence of weevil attack and the intensity of the management program.

Time spent in site investigation and evaluation is, therefore, a must, and worthwhile. Compounding the conversion question is the fact that most suitable pine sites are on small private ownerships. However, that should not deter the effort. That presents the number one challenge. The second challenge is the investment and length of time it runs, but that should not deter us either. The least challenging aspect of this affair is the technology, because we have it, and we can do it! Having said that, we will tackle the technology.

The case for converting suitable forest land to white pine will become more apparent with the passage of time, presuming that the demand for this tree increases or even remains static. According to <u>Forest Statistics for Maine, 1971 and 1982</u>, the acreage of seedlings and saplings is down from 368,300 acres in 1971 to 61,100 acres in 1982.

This may be somewhat misleading as there are many acres where white pine is in the understory and did not get counted, but has the potential of becoming future crops, either by release through logging, intentional cultural practices, or by perseverance. Eastern white pine is a very tenacious and persistent tree; after all, we have been cutting it for more than 350 years. These statistics also indicate that we have been relying on the site preparation of the early land clearers for the raw material base and are now running out of those pure stands. It also says that we have been utilizing this resource with little regard for its future. The bottom line suggests that the future of the white pine industry is dependent on better logging and cultural practices and a strong tree-planting program. The planting program will be by far the most important, if we are to have ample raw material 60 to 70 years hence. It will have to consist primarily of conversion to eastern white pine where it once was found naturally--at least to begin with.

Primarily because of poor cutting practices with little regard for future crops, there are thousands of acres of primary pine sites now in low grade, low or no value hardwoods with very poor growth rates. These species include scrub oak, red and black oak, poplar, gray birch, and red maple. Converting these sites to eastern white pine is a logical, justifiable endeavor for the following reasons:

1. To insure a viable industry

2. Pine is definitely the most valuable tree that can be grown there

3. Pine is, by far, the fastest growing and highest volume producing tree on these sites

4. These sites are least expensive to convert

5. The so-called energy crisis has spawned the technology to get site preparation done at no cost.

Conversion is not new, as it has been done in Europe for years. It has been done on industrial ownerships in the U.S. and Canada, and also on public ownerships in the U.S. It is something that cannot be done at will on any site for both economic and biological reasons.

The first question to ask is what are the best sites for conversion to eastern white pine. The answer is glacial outwash and glacial tills that are somewhat excessively drained to excessively drained. Glacial outwash is sands and gravels deposited by water running out of or off from melting glaciers. Tills are usually a jumble of materials from clay particles to boulders, and got dumped in place when the ice melted. These two soil groups are excellent because pine can compete much more effectively with any hardwoods that are present.[1] On these suitable sites, eastern white pine becomes very persistent, even under a hardwood canopy, and can be released over the next 30 years with success if, for any reason, you are unable to perform the necessary cultural practice in a timely fashion.

The next question is how do you go about getting the site ready. There are a number of procedures, including:

1. Site preparation and planting in one pass with a V-blade plow and planting machine

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[1]The more moist phases of glacial tills will present more competition from the hardwoods and generally will cost more to get pine established.

2. Aerial application of an herbicide

3. Conventional commercial cutting

4. Plowing, harrowing, scalping

5. Silvicultural clearcut for fuel chips (so-called biomass or whole-tree chipping on site).

The size of the trees already on the site will determine the way to go, including the possibility of waiting 5 years or so for a silvicultural clearcut that is commercial.

At the present time, a silvicultural clearcut that is commercial, utilizing on-site chipping for fuel, seems to be the most appropriate because it prepares the site at no cost and leaves it clean for planting, either by machine or by hand. Planting by hand seems to be least expensive, even in these "high tech" times.

The question of whether to plane bare-root seedlings or containerized stock is probably best answered by the number of trees to be planted vs the number of people to plant them in a given period of time. I find that 3-year-old seedlings get the best start and that containerized stock are more valuable in extending the planting season. The optimum time to plant is in the fall of the year when the cutting was done, even though soil compaction from equipment can be a problem, particularly on skid roads. In Maine, planting can begin as soon as seedlings are hardened off in the nursery until the middle of September. The reason for the cutoff date is to make sure that the seedlings' root system gets established well enough to give the trees a head start compared to spring-planted stock. Also, the first year's growth in height will usually surpass that of trees planted in the spring. During planting, seedlings with skimpy root systems, runts, or other diminutive stock determined by visual observation should not be planted. Trees should be planted 6 X 6 feet maximum. It would be advantageous to have genetically superior stock that will take off fast after planting, to eliminate the need for chemical control of hardwood on these sites. Usually, if it is necessary, one application of herbicide will bring through a satisfactory stocking of pine.

After the plantation is established, it should be left alone for the next 25 to 40 years, depending on such matters as the incidence of weevil attack and the prevalence of undesirable hardwoods in the stand. The elimination of any residual hardwoods that might be present can be done at any time; however, thinning is a matter that too often is done too soon. We sometimes, as foresters and as members of the instant gratification society, think it necessary to start doing something the minute the branches touch. Not so, when dealing with white pine. The tree does not stagnate because certain individuals have superior growth qualities that allow them to beat their neighbors. It is also a tree that you can find basal areas of 200 to 300, which indicates that it is a fierce competitor and high-volume producer in terms of fiber alone.

So, when is the right time for the first thinning? If there is, for all practical purposes, no weevil problem, make a fourth row biomass thinning at about age 25 and prune up to 100 of the best dominant trees, considering that one more row thinning will be made in the middle row of the three rows left from the original. If the weeviling has been heavy, take every third or fourth row at age 35 to 40 and prune up to 100 of the best dominant and codominant trees. This will be a commercial thinning and could be either a conventional or biomass operation. Pruning should be to 17 feet in either the 25 or 35 year situation. In any case, remove no more than one-third of the live crown. In the older weeviled stand, some of the trees pruned will have some yanks and crookedness; however, recovery to straight trees will be surprising over the life of the stand. Thinning thereafter should be individual trees, and ideally every 10 years, removing no more than 20 to 30 percent of the crown canopy each time. The purpose is to keep hardwood under control and to establish reproduction. When reproduction begins to appear, it should be encouraged, regardless of the age of the stand. If an application of herbicide is necessary, apply it. At the point where reproduction is well established, each successive commercial cut can be somewhat heavier, depending on what size you expect the final trees to be. (Personally, I like pine trees 36 inches in diameter, although some mills think that is too large.)

If we are to promote the white pine industry, maybe even save it, it will be necessary to get good pine sites back into production. In most cases, that means eliminating inferior hardwoods and planting. The method of conversion most practical, at the present time, is on-site chipping, achieving a silvicultural clearcut preparatory to planting. Planting is more successful if done in the fall early enough for root system establishment and a head start at beating the hardwood competition. Stock with genetically superior height growth attributes in the first years after planting would greatly assist in eliminating the need for later release by herbicides. After establishment, the plantation should not be thinned until it is at least 25 or as much as 40 years old, depending on the incidence of the white pine weevil.

If foresters and landowners would exhibit the inclination, the perseverance, and the patience, they would find the growing of white pine can be a productive pleasure in the years ahead.

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NATURAL WHITE PINE REGENERATION:

SITE REQUIREMENTS

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The nature, extent, and past management of the white pine resource on the Menominee Reservation is described. Findings from early regeneration efforts using the shelterwood system are reviewed. Site selection, crown density, and scarification are identified as critical factors in white pine regeneration. The integration of these site requirements into a regeneration prescription is discussed.

Introduction

The Menominee Indian Reservation, a forest which has survived as an island of sawtimber in an ocean of cleared land, is located in North Central Wisconsin, approximately 60 miles northwest of Green Bay, Wisconsin. It consists of ten contiguous townships that have always been part of the Menominee Indian Nation's original land settlement area. Of the 230,000 acres on the Reservation, 220,000 acres are forested. The white pine portion of the Menominee Forest consists of 30,232 acres of sawtimber, 1,487 acres of poletimber, and 1,734 acres of saplings and seedlings, for a total of 33,453 acres.

White pine has always been an integral part of the forest resource on the Menominee. The forest lies within one of the old pinery areas of Wisconsin an area now largely devoted to other land uses. Natural and man-made disasters are not uncommon in the history of the Menominee Forest. Almost all existing large white pine stands trace their origin to one of these occurrences.

Current forest inventories indicate a decline in acreage in the large white pine sawtimber class. Closer examination of the inventory data indicates that although a loss of large white pine acreage is occurring, an off-setting acreage of white pine is regenerating naturally in other parts of the forest.

The white pine forest has been managed under the single tree selection method for the last forty years. Many of the existing large pine stands are growing on higher quality melanized-podzol soils, and are converting to hemlock, red maple, and sugar maple. On the other hand, the less fertile sandy podzols exhibit a natural conversion to white pine beneath stands of aspen, jack pine, red pine, and to some extent, white pine. Existing silvicultural prescriptions for white pine differentiate between two sites: light soils and heavy soils. Management on light soils is designed to favor pines, while that on heavy soils favors conversion to hardwoods. Although the existing prescription is intended to encourage white pine on sites where it is most suited, all sites are converting to hardwood timber species to varing degrees. Very little white pine regeneration is occurring under large white pine sawtimber.

As a result of the lack of white pine regeneration, and the declining growth rate in many of the old pine stands, attempts were made to alter the situation. The first concerted trial was made in 1964, on what appeared to be a lighter soil, suitable for white pine regeneration. The classic textbook approach to white pine regeneration was tried. Basal area control was used in a shelterwood cut. Two thinnings occurred over a seven year period, reducing the white pine basal area from 220 square feet to 90 square feet per acre. Treatments using various combinations of discing, herbicide control, and seeding were included in the trial. The results were very erratic. Very few seedlings became established, and the invasion of hardwood and brush was prolific. The key observation made from this attempt was that high shade from the overstory was not detrimental unless very excessive, while low shade from understory brush retards pine germination and growth. Beyond this observation, however, it was difficult to make further clear correlations between crown density levels, scarification, brush control, and seedling establishment.

This difficulty arose from the inability to adequately evaluate site, and accurately measure crown density, as well as the lack of availability of suitable equipment for seedbed scarification and brush control. Within the last five years, however, this lack of technology and equipment has largely been overcome. As a result, a series of trial areas were established to systematically evaluate the cumulative impact of site, crown density, scarification, and brush control on the various stages of seedling establishment.

Investigative Phase

One of the major obstacles to be overcome was the need to identify the "least common denominator" of all of the factors involved, i.e., that factor which must be common to all stands in order to make valid comparisons between and among various treatments. In an effort to develop a workable prescription for natural white pine regeneration, an attempt was made to examine each phase of the process in detail. The objective was to identify this "bottleneck" in the regeneration process and to evaluate possible alternative solutions.

Site Evaluation

Early attempts at site evaluation based on cover type and broad soil classifications led to erratic, unpredictable results. In an effort to reduce this variation, ways to define a more homogeneous site were investigated.

The classic soil survey/soil mapping approaches were evaluated and found inadequate for a number of reasons. Soil mapping units were found to be too broad. Correlation between soil characteristics and tree growth were unclear. Non-soil environmental factors affecting tree growth were not considered. In addition, application by field foresters was difficult. Soil type boundaries and subtle changes within mapping units were hard to identify. Minor differences between mapping units were hard to evaluate in terms of silvicultural impact.

The Habitat Classification System developed by Coffman, et al (1983) was also investigated. A habitat type is a land unit characterized by a particular plant species mixture (with emphasis on ground vegetation) that would naturally develop on that site in the absence of disturbance. This implies that plant communities of different species combinations occur on land units when the sum total of environmental factors differ significantly. Habitat types are recognized by Key Indicator Species which are present even when a land unit is not occupied by its climax plant association.

Field investigations have shown this system to be very sensitive to changes in site factors related to vegetative response. When viewed in terms of habitat type, past stand treatment responses began to take on a definite pattern. The system also proved useable by field foresters. The Menominee and the D.N.R. forestry staffs are currently working with Dr. Kotar of Michigan Technological University to refine the system and expand the productivity and silvicultural data for the habitat types specific to the Reservation.

Natural Seedfall

In order to determine if natural white pine seedfall was adequate, seed was collected in five mature stands during two seed years of average or better production. Seed crops were found to range from 334,000 to 980,000 seeds per acre. At an average rate of 27,000 seeds per pound (USDA Forest Service, 1965), these rates would amount to between 12.4 and 34.7 pounds of seed per acre.

Seed year frequency also appeared adequate. Based on seed year records in northeast Wisconsin for a 34 year period (Godman, et al, undated) there have been 19 years when the seed crop was adequate. Generally, a seed crop sufficient for regeneration occurs every other year.

Seed Viability

Seed viability was evaluated in two ways. Seed was collected from two stands and hand planted in flats in controlled germination tests. Seed was also outplanted in rodent exclosures and under shelter cones to assess germination under field conditions. Indoor germination rates were 85%+. Field germination rates (in rodent exclosures) were: 30% on unscarified microsites, and 65% (exposed seed) to 72% (buried seed) on scarified microsites.

Rodent Losses

The impact of rodents on the seed crop was assessed by comparing seed losses of exposed and buried seed with those in rodent exclosures. Seeds were individually sown in October and November of 1981. Those seeds missing the following June were assumed to have been eaten by rodents. Based on these trials, it was estimated that 95-98% of exposed seed and 94% of buried seed was lost to rodents.

No difference in rodent losses were found between untreated seed and those treated with Tersan 42-S + aluminum flake and Endrin + Thiram + aluminum flake.

Even allowing for rodent losses of 98%, in a normal seed year, from 7,000 to 20,000 seed per acre should survive. With an average germination rate of 65%, this still gives the potential of 4,500 to 13,000 seedlings per acre. These estimates are very conservative. First year seedling counts taken in six scarified white pine stands following a good seed year ranged from a low of 20,800 to a high of 480,800 per acre.

Germination

In past observations, it was found that white pine would, in fact, germinate under full shade. An attempt was made to evaluate the change in per cent germination due to modification of moisture and temperature conditions through scarification.

Based on seed trials in scarified and unscarified seedbeds, it was found that scarification increased germination rates five-fold on dry sites and two-fold on more moist sites.

Scarification also increases soil temperatures significantly. 1/ The increased temperature encourages earlier germination. The earlier in the season that germination occurs, the greater the probability of survival (Graber, 1968).

Early Survival

Although white pine will germinate under full shade, observations over the course of the growing season showed that they would not survive. Supression losses were heavy and those seedlings still alive at the end of the growing season had very

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1/ Godman, Richard M., personal communication.

poor vigor. The spindly seedlings were crushed beneath the leaves in the fall and virtually none were alive the following spring.

Based on observations of seedlings under more open aspen and jack pine canopies, it was found that 70-80% crown density resulted in good seedling survival. The resulting seedlings were more vigorous and strong enough to resist leaf crushing in the fall. The lighter canopy also tended to cause the leaf litter to dry out and curl up, unlike those under a more dense canopy which tend to form a permanent, damp mat. This phenomenon, in conjunction with the increased seedling vigor, reduces the impact of leaf crushing dramatically.

When combined with a sufficient reduction in canopy density, scarification was also found to have a substantial impact on first year survival. Opening up the canopy increases growth and vigor of the seedlings, but at the same time, raises surface temperatures and dries out the duff layer. Seedlings not rooted in mineral soil suffered heavy mortality during the typically hot, dry months of June, July, and August. Seedlings growing in mineral soil scalps were found to have a survival rate 3 to 10 times higher than that of those on unscarified microsites after two years, depending on soil type. This increased survival rate, coupled with the two to five-fold increase in germination rates, means a seed falling on a mineral soil seed bed had a six to fifty times better chance of resulting in a live seedling at the end of the second year.

The scarifier used on our trials produced a variety of microsites, both in terms of relief (elevation) and in degree of mixing of mineral and organic soil layers. Observations revealed that the best seedbed for germination and early survival was a mixture of mineral soil and organic material at the approximate elevation of the soil surface. Lower microsites tended to fill with hardwood leaves and smother the seedlings, while elevated microsites tended to dry out.

Establishment

After the first year, hardwood and brush competition were found to be the dominant factor in survival and establishment. Early trials showed that excessive overstory removal (to less than 60% crown density) ultimately favored hardwood and brush development and resulted in loss of the white pine. It was also observed that hardwood development would be retarded by retaining canopy densities of 70-80%.

With the development of the Habitat Classification System in Wisconsin, it was possible to predict the response on a given site to a given level of cutting with some degree of accuracy. Using this system, initial determination was made as to which sites to manage for white pine and which to convert to hardwood.

Herbicide site preparation trials demonstrated that Glyphosate applied with ground spray equipment was effective in controlling hardwood and brush competition.

Partial overstory removal trials in stands with an established white pine understory showed that reductions to 40% crown density could be made without significant white pine weevil damage.

Current Recommendations

An integration of the factors required for natural regeneration results in a general prescription (Table 1) that allows for more specific application based on individual site differences.

A. Site Selection

Based on the Habitat Classification System, the site is evaluated according to its relative potential productivity and the expected degree of hardwood regenerative competition. Priority selection is given to those sites with highest growth potential for white pine relative to the degree of effort required to effectively treat hardwood competition. It cannot be economically justified to attempt to grow white pine on the best hardwood sites, because of prohibitive establishment and maintenance costs.

B. Timing

Employing a shelterwood system, the actual regeneration operation -- site preparation, scarification, and crown density thinning -- may span up to two years. It is timed to occur at a minimum of thirty years prior to the anticipated overstory harvest.

C. Site Preparation

On the Menominee Forest, all white pine stands, regardless of habitat type, face the potential of hardwood competition to some degree. Thus, it is desirable to remove the understory hardwood through a separate commercial operation, if feasible, or a non-commercial operation, if necessary. Depending on the site, it may be required to chemically treat any hardwood competition that cannot be economically harvested, as well as any other broadleaf vegetation that constitutes the low or secondary canopy. The objective is to effect a site condition in which the amount of sunlight reaching the seedbed is controlled through manipulation of the dominant/co-dominant crown density. Under this method, if the understory hardwood removal can be achieved prior to the start of the growing season, with a subsequent chemical treatment late that same summer, much of the hardwood stump sprouting may also be controlled.

D. Scarification

Frequently, exposure of mineral soil through the normal logging operation is inadequate to in-

Table 1. Prescription For Natural Regeneration Of White Pine

Step	Process	Notes
1. Evaluate Site	I. Habitat Classification System	Recommendation "A"
2. Prepare Site	I. Removal of all understory hardwood a. commercial operation, or non-commercial operation b. herbicide application, if necessary	Recommendations "B" & "C"
3. Scarify	I. Double scarification, at right angles	Recommendation "D"
4. Thin Overstory Canopy	I. Reduction of crown density to 70% to 80% a. thin from below b. descriminate against hardwood	Recommendation "E"
5. Release Seedlings	I. Herbicide release of young seedlings, if necessary II. Reduction of overstory crown density to 40% to 50% at onset of rapid height growth; least valuable trees are left III. Maintenance of crown density at 40% to 50%	Recommendations "F" & "G"
6. Remove Overstory	I. Regeneration attains 5.0" d.b.h. a. removal of overstory, if feasible or b. forego harvest cut	Recommendation "H"

sure complete stocking of the site. Because of this, mechanical scarification through use of any one of the double-row patch scarifying machines currently available, is necessary. In practice, a scarification pattern is employed in which two passes are made over the site, with the second one being made perpendicular to the first. This must be performed when the ground is not frozen, and prior to the regeneration cut, to insure the best coverage of the site. This exposure of mineral soil creates an ideal seedbed, that generally remains viable for at least two years. As Menominee forest lands experience an adequate white pine seed crop on an average of every other year, the timing of the scarification will usually coincide.

E. Crown Density Thinning

The initial crown density of the dominant/co-dominant canopy is evaluated. Because of the number of varying factors, principle of which are site, stocking, crown development, species composition, and average stand diameter, basal area is not a precise indicator of crown density for regeneration purposes. The overstory crown density is reduced to a level of between 70% and 80%, with the lower range being the goal on sites where minimal hardwood competition is expected. The reduction is made by thinning from below, descriminating against hardwood. This crown density level should attempt to maximize the microsite for white pine, while minimizing it for hardwood.

F. Initial Release

In a few instances, it may be necessary to release these seedlings from low vegetative competition on some sites. A light application of herbicide, two or three years after seedling establishment, appears to effectively accomplish this. Seedlings younger than this age have been adversely affected by this chemical release.

G. Subsequent Overstory Reduction

The first scheduled cut of the overstory following establishment of the seedlings is timed to

coincide, if possible, with that period of seedling development in which height growth begins to accelerate rapidly. The stand is thinned to a dominant/co-dominant crown density of 40% to 50%, leaving the least valuable trees. (If the seedling stocking is inadequate, this cut is delayed, with the crown density held at 70% to 80% until a determination of the cause of failure can be made. The recommended sequence can then be reinstituted at the appropriate stage necessary to create the ideal site conditions.) The stand is held at 40% to 50% crown density through periodic thinnings, always leaving the least valuable overstory trees. The number of stand entries should be minimized.

H. Overstory Removal

When the regenerated stand reaches pole size (minimum of 5.0" d.b.h.), the overstory should be completely removed, if feasible. However, the damage to the younger stand during harvest operations must be evaluated against the gain to be expected from the removal volume. Because this logging damage (principally from skidding) may at times be unacceptable, the final cut can be cancelled. Since the previous overstory thinnings subsequent to seedling establishment have left the least valuable trees, eliminating the final cut will minimize damage to the regenerated stand, and restrict financial loss to the lowest value timber. The long term result may therefore be a net gain.

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RELATIONSHIP BETWEEN PRUNING AND THINNING

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Economic managc_ent of white pine depends on producing lumber which is either clear or free of loose knots. Artificial pruning is essential and so is the severe and very early thinning that ensures rapid diameter growth. Pruning heights, rates of retreat of bases of green crowns, thinning schedules, diameter growth rates, and rotation lengths interact with each other and must be planned.

Necessity for Intensive Silviculture

The growing of white pine for timber is something that should be done well or not at all. Most of the problems are best solved early in the lives of trees or stands. However, devising of solutions depends heavily on deciding about the characteristics of target trees of the final crop and working backwards to determine the details of the early treatments needed to produce such trees.

The quality and value of white pine wood and trees ranges from magnificently high to discouragingly low. Substantial silvicultural investments are necessary to grow good white pines but, if stands are managed aggressively enough, prospective returns seem high enough to justify the costs.

Since the wood of white pine is not very suitable for pulp or framing timbers, its management should not be confused with that of loblolly, red, or other hard pines. Actually it is more like managing hardwoods because most of the value is generated by proper management of a comparatively small number of trees per acre. In fact, the wholesale prices of high-quality white pine lumber are higher than those of most hardwoods. Moreover, the lower density of white pine wood and the higher photosynthetic efficiency of the evergreen habit make it possible to grow more wood volume and carry more trees per acre.

Stand Origin and Problem of Growing Straight Trees

In most parts of the white pine range, the critical problem is dealing with the white pine weevil (*Pissodes strobi*). The only major exception appears to lie high in the Appalachians south of Pennsylvania; there weevils are rare and white pine makes its best growth of all, but on limited areas. One aspect of the weevil problem is the fact that the dead terminal shoots can ultimately become infection courts for early red-rot infections (Ostrander and Foster, 1957.)

The essential intensive thinning and pruning treatments must start with adequate numbers of straight trees.

The ways of getting to this starting point vary with stand origin. Most experience has been with old-field stands or plantations that started on abandoned grassy fields. It is these that, in the poorly managed condition, have given white pine its bad modern reputation. If treated early enough, stands of this kind can usually be redeemed by selection thinnings aimed at freeing reasonably straight codominant trees from badly weevilled dominants. This is best done by precommercial thinning; the straight trees suffer too much loss of live crown and diameter growth if one waits until the stage of commercial thinning.

There are also important possibilities for using insecticides to protect a sufficient number of dominant trees from weevilling. If original dominants could become final crop trees, rotations could be shortened significantly and plantation silviculture of the species would be more truly feasible than it is now.

Another kind of free-growing white pine occurs as scattered emergent trees in the spruce-fir type. Here white pine outgrows its associates from the beginning. The incidence of weevilling is comparatively low, perhaps because the host population is low.

The few white pines that grow in association with hardwoods are often of good form. However, because white pines grows more slowly than most hardwoods in the juvenile stages, these are usually the few survivors that have managed to grow up in "chimneys" formed by the surrounding hardwoods. Fortunately natural pruning is often good in mixed stands; it is not always feasible to seek out scattered trees for artificial pruning. Such trees can ultimately become impressive emergents and often grow well for long periods after they attain this status.

One effective way of starting good, new stands is by so-called irregular shelterwood cutting in which sufficient numbers of straight trees are produced by keeping the new stand under the old for long periods until the new pines are about one log tall. This provides adequate weevil control (Foster, 1953) although it requires careful logging to protect the new stand during the final removal cuttings.

As brought out in other parts of this symposium, effective regeneration of white pine usually depends on some sort of control of competing hardwoods.

Live-Crown Management and Artificial Pruning

After there are enough straight pines the next major problem is that of managing the branches. The rot resistance of white pine induces poor natural pruning and loose-knotted lumber. Nothing, except weevil damage, discourages white pine management more than the fact that at least half of the lumber produced from untended stands is loose-knotted and has a true stumpage price approximating zero. The only good branch is a live one.

Artificial pruning is essential. If there were some regulation that allowed only one North American conifer to be pruned, eastern white pine would be the logical choice. It could probably be shown that pruning would be financially advantageous merely by preventing loose knots. However, the possibilities of producing wide, clear boards of the kind now seldom seen on the market are much more attractive. Red, tight knots do not cause serious problems; they are even attractive enough to be desirable for some purposes. The way to produce boards that have red knots is to thin the stands to keep the branches alive; refraining from pruning by itself is not enough.

The first pruning is ordinarily best delayed until the trees have attained the height of the first log-length so as to avoid pruning trees that might later be seriously deformed by the weevil. If the first log-length of the tree is straight when the pruning starts, the weevil cannot make that crucially important portion of the stem crooked. It is also well to wait until the trees have differentiated into crown classes so that one has a better way of assessing the vigor of each trees.

It is also well to delay the first pruning until after the first thinning. This is mostly to ensure that the trees selected for pruning will grow rapidly. If the first pruning follows the first thinning there is less risk of physical damage to the pruned trees. These considerations usually mean that few white pines are pruned until they are 6 inches DBH. On the other hand, if one wishes to take advantage of rapid diameter growth and develop thick shells of clear wood, it is well to be wary of pruning trees much larger than 10 inches DBH.

Ordinarily the kinds of restrictions on growth that are associated with partial shade or high initial stand density cause most lower branches to be dead before the time comes for pruning. Under such circumstances it is possible to confine most of the pruning to removal of dead branches. This avoids any problems with bark-tearing or heart-rot that might be caused by green pruning. However, there never has been much evidence of problems with green pruning in eastern white pine, at least if the removal of large branches is avoided. It is possible that heart-rots could be introduced if heartwood, which does not pitch over, was exposed by pruning large branches although there seems to be no solid evidence about the matter. The pruning of large branches is also time-consuming.

Where it is or becomes possible to grow straight white pines in the open it is logical to consider wide initial spacing and green pruning. With this it is necessary to resist temptations to cut off excessively large branches or to stunt height growth by reducing live crown ratios too much.

The question of how high to prune is governed mainly by the limitations of the available equipment. Efforts to mechanize the operation have not so far been successful; they are discouraged by the near absence of any premiums for freedom from knots in second-growth Douglas-fir and southern pines. Ordinary power-saws can be used with acceptable safety only close to the ground. Otherwise the work must be done with hand-saws or other manually operated tools.

Pruning can be done rather cheaply at heights up to 9 feet which can be reached with pruning saws mounted on axe-handles. This will normally be enough to prune the first plywood veneer bolt in a tree. Higher pruning requires pole-saws, ladders, climbing spurs or acrobatics done with climbing ropes.

Pole-saws and ladders become too wobbly when attempts are made to prune higher than about 22 feet with them. Foster (1957) found that wounds from climbing spurs caused no damage to white pine wood other than the formation of pitch pockets which do not count as defects. With these or climbing ropes it is possible to prune far above the ground if one can find workers who are sufficiently brave, agile, and expert. If the worker can ascend to the level of the branches that are to be removed, the work is less tiring than cutting with a saw on the end of a long pole.

The usual reaction to these problems has been to restrict artificial pruning to the first 17.5 feet so as to ensure treatment of the first standard 16-foot log. In New Zealand and Australia, where pragmatism reigns, the limitations of wobbly pole-saws set the standard height at 22 feet. White pine is not often used for the 8-foot framing timbers that are the modules on which the 16-foot standard log length is based. In fact, in much of New England, 12 feet has actually come to be the common log length. The utilization is much like that of hardwood lumber in which the 2-foot piece free of defects is the basic unit. If these things be true, any pruning height of 9 feet or more would seem justifiable.

Pruning is usually done in two or more stages with a different length of tool or ladder for each zone of height. Where pruning is done to heights of 17 feet most time studies indicate that it is more economical to do the work in two stages rather than three because of the difference in cost of getting to the stand and walking between trees. Because the lowest branches are usually small, it is possible that not much is lost by pruning the first log in one step. However, if pruning is done in stages it may be logical to prune more trees in the first or lowest stages with the number becoming fewer and the choices more discriminating as pruning is carried to higher and costlier zones along the tree stems.

In selecting trees to prune the growth potentialities must be weighed against the conflicting considerations of branch size and stem straightness. Unfortunately high vigor in white pine is associated with vulnerability to weevil deformities and a high propensity to form large branches. In many badly weevilled stands it may be that no perfectly straight trees can be found in either the dominant crown class or the more vigorous codominants. Under such circumstances there is a tendency to select some of the more feeble members of the codominant class. Although the shade tolerance of white pine is great enough that such trees can respond to assiduous efforts to release them, this response is usually rather slow. Under such circumstances, is it generally better to be content with selecting codominants that are moderately straight and moderately vigorous.

The form of rapidly growing stems can improve remarkably over the decades. The senior author has observed several old-field plantations in southern New England which were regarded as absolutely beyond redemption in the 1940's but which now have trees that are regarded as moderately good. Weevil-caused deviations of less than 2 inches of horizontal distance from absolute straightness are ultimately of no consequence in white pine stems (Hawley and Clapp, 1935). It is also worth noting that a crook at the end of a potential log-length is not of great consequence. Furthermore, much of the utilization of white pine is in lengths short enough that it may not be necessary to be preoccupied with developing perfect 16-foot logs.

If one does prune weevilled trees it is logical to carry the treatment upward to just short of the large branches that often form at the base of a weevil crook. If that is ultimately going to be the end of a log, it is not logical to sever these particular branches because the knots will be removed in end-trimming boards. Such branches are also costly to remove. However, it is highly desirable to break off the old dead terminal shoot if it still projects at that point. These stubs, with the grooves left in them by the weevil larvae many years ago, are "snorkels" through which water, oxygen, and spores of *Fomes pini* can enter to cause red-rot infections.

Coordinating Thinning and Pruning

Decisions about pruning height should control many other choices, most notably the entire thinning schedule. The ideal combination of pruning and thinning regime is one in which the pruning is completed and severe thinning started just as the bases of the live crowns have retreated to the chosen final pruning level. Not only does this prevent loose knots but it also induces rapid diameter growth and the production of substantial amounts of the kind of clear soft pine lumber that has always been in demand.

As is the case with hardwoods and many other species, one must seek to balance the branch-free length of stem against the lost diameter growth that must be paid to get it. If pruning is limited to the first log, it becomes logical to thin drastically in order to prevent dying of branches; this will induce rapid diameter growth, substantial stem taper, and rather short rotations. One factor that may limit rotation length could be the development of excessively large live branches at the base of the live crown.

On the other hand, if pruning can be carried to greater heights, as was advocated by Foster (1957), the production of clear wood over greater bole length may make it logical to grow trees to much larger diameters on longer rotations.

Regardless of how high the pruning is carried, it is not possible to secure attractive financial returns from this kind of high-investment silviculture without heavy thinning. The thinning must indeed involve deliberate, resolute sacrifice of cubic volume production in order to grow pines of large diameter that will produce wide, clear boards. The purpose is not, as it might be with loblolly pine, to maximize the combined production of pulpwood and 2x4 framing timbers.

The production that is seemingly lost by growing deep-crowned fat trees need not be wasted. If the weevil is to be controlled by starting the new stand in the partial shade of the old one, some of the space that is opened up late in each rotation to make pruned trees grow fast can be used partly by new regeneration. What might otherwise act as a heavy thinning 25 years before the end of the rotation might also be the step in shelterwood cutting that caused the next stand to start. The ideal would be a final removal cutting of the fine crop trees which released a stand of straight pines, as tall as the length of the first log, ready for the first precommercial thinning and pruning. Perfection would be a situation in which the final crop trees had just closed over the new stand to say nothing of having logging equipment completely suitable for the system.

Our information about the dimensions of desirable final crop trees is based on observations of trees at the Yale Forest in southeastern New Hampshire that had been pruned in 1936 and then completely released by the 1938 New England Hurricane. The trees had been pruned to 17 feet when they were 7-8 inches DBH. Observations made by the senior author and Alan C. Page in 1965 showed that such trees could grow to 20 inches DBH in somewhat less than 30 years and suffer little or no branch dying. Such trees earned compound interest of 10 to 13 per cent, above inflation, on the costs of growing them or, alternatively, on their own value at the beginning of each 5-year growth period. It also seemed probable that one might grow about 50 such trees if they fully covered an acre but with a new crop of saplings ready to thin and prune beneath them.

Subsequent observations of these trees indicate that the rates of compound interest return sag below 6 per cent about the time the trees grew to 22 inches DBH. However, by that time competition with contemporaries was starting and it has not yet been determined whether thinnings done a few years ago have rejuvenated the growth and earning power of these trees.

In his study of the potentialities of high pruning Foster (1957) presented data that allow us to calculate the internal rates of return that might be produced by pruning trees to 54 feet and letting them grow to diameters of 30 inches and ages of 125 years. The rates of compound interest seemed to remain above 5 per cent even to that age and size. The question becomes one of how high the pruning is carried and how long the rotation is to be. The ability of white pine to continue height growth to remarkably tall heights and great ages gives unusual latitude for choice of rotation lengths.

Regimes of rapid diameter growth often raise fears, justified or otherwise, about impairing wood quality. Most of these fears are really based on serious problems with the properties of juvenile wood in the central core of tree stems. This kind of wood is laid down within a given segment of tree stem before it is subjected to the effects of thinning and pruning. Furthermore, the wood of white pine is much more uniform in anatomical structure and density than that of almost any other species. Even the juvenile wood causes fewer problems than is the case with most species. If it is a problem, it may be noted that the same slow growth in partial shade that protects young trees from weevil damage also virtually eliminates juvenile wood.

It should be noted that wood from trees with large crowns would have an unusually high proportion of sapwood with tendencies for bleeding of resin; this would not be a problem with kiln-dried lumber.

Stand Density Guidelines for Thinning

The studies of the target trees showed how much growing space they occupied but not how many others might also be grown in the space that the final-harvest trees might ultimately occupy. For this purpose we developed a tree-growth model in which wood production is "driven," as it is in nature, by crown size. Crown projection area is the parameter of stand density and tree height (an integrated expression of age and site quality) that of the stage of stand development; these two parameters in combination also provide a way of expressing the historic or total crown volume of the average tree. The model does, at present, rest on the overly simplified assumption that all trees in a stand are the same.

The model, described in detail by Seymour and Smith (in review) was based on a decade or more of observations of the crown expansion and volume growth of 122 pines of varying sizes and crown dimensions at the Yale Forests in Connecticut and New Hampshire. Table 1 shows the possible DBH's that can be achieved at different stages in the rotation if prior thinnings have been heavy enough to permit crowns to cover the stand area completely. These data can be used to derive thinning schedules, including the required stand densities or between-tree spacings, to reach any "target" DBH at the specified height.

If artificial pruning must be limited to the first 16 or 22 feet and subsequent branch dying is to be prevented, the thinnings must be more drastic than those, such as presented by Lancaster and Leak (1978) and based on criteria used for most other species. Most of any additional board-foot volume that might be gained from lighter thinning would be loose-knotted and thus of negligible stumpage value. Therefore, the thinning should be the most severe that is still consistent with having the trees of the final crop fully occupy the site at the end. In other words, the ideas about "low-density management" presented in other papers of this symposium seem most appropriate.

Somewhat less severe thinning could be justified but mainly if one were willing to prune more than the first log of the tree and plan a longer rotation.

Table 1. Predicted DBH for for eastern white pine at various stand heights and densities (or between-tree spacings), assuming complete crown closure

Stand height, feet	Number of trees per acre: 1210	681	436	303	194	109	70	48	36	27
	equivalent square spacing in feet: 6	8	10	12	15	20	25	30	35	40
40	4.9	5.8	6.5	7.2	8.2	9.6	--	--	--	--
50	5.7	6.7	7.6	8.5	9.6	11.2	12.7	--	--	--
60	--	7.7	8.7	9.6	10.9	12.8	14.5	16.0	--	--
70	--	--	9.7	10.7	12.1	14.2	16.1	17.8	19.4	--
80	--	--	--	11.7	13.3	15.6	17.7	19.6	21.3	23.0
90	--	--	--	--	14.4	17.0	19.2	21.3	23.2	24.9

Conclusion

Eastern white pine is not a standard kind of pine and its silviculture cannot be conventional if it is going to succeed financially. Artificial pruning is a costly but imperative operation. Pruning and thinning determine the height of the base of the live crown which is a crucially important parameter of managed trees that is often overlooked. The need for pruning dictates heavy thinning which must start just before the first pruning. The schedules for subsequent thinning should be aimed at optimizing financial returns, not at maximizing production of cubic volume. The key is rapid diameter growth and thoroughly analyzed treatment of the small number of trees that form the final crop. It is a case of not letting the forest hide the trees.

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MANAGING WHITE PINE IN ONTARIO

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White pine was the primary incentive for the development of access, both road and rail, through most of Central and Southern Ontario. What was thought in 1867 to be an inexhaustible supply has now been depleted to the extent that white pine is no longer a significant commercial species in many areas it once dominated. Improved shelterwood management techniques, which reduce damage by white pine weevil, and more determined site preparation, planting and tending programs are slowing the rate of depletion, but are still far from reversing the direction. In the face of a relatively constant demand, a strong commitment to the maintenance of white pine, coupled with consistent funding, will be required to ensure that a sufficient future supply is available.

When the first settlers faced the pine forest of Ontario it must have been an intimidating sight as it represented a formidable barrier to the agricultural development of the land. The same forest, however, was the foundation of early industrial Ontario and it both literally and figuratively fueled the rapid expansion of the Canadian frontier. As the forest in an area was depleted, the timber trade moved further up the rivers and extended the railways leaving behind settlements and lines of commerce.

In the mid 1800's the supply of white pine in Ontario was frequently described as "inexhaustible" and estimates suggested there was enough to last 700 years. By the early 1900's most of the old-growth mature stands of Central Ontario had disappeared. Although there are still significant remnants of these stands stretching from the Lake Temagami area to the Lake Superior shoreline, they are a far cry from the huge pine forests that supplied the peak production of more than 800 million board feet of white pine lumber between 1908 and 1911.

The most current inventory now estimates the area of the white pine working group in Ontario at approximately 1.5 million acres of which 80% is in Crown or public ownership and the remaining 20% is privately owned. Much of this area is now occupied by second growth stands which originated after the heavy logging and fires which so characterized the heyday of pine logging. Most of the white pine stands in Ontario are of fire origin; however with improved fire control the use of harvesting methods which concentrate on harvesting, with little or no regard for the re-establishment of a new stand, could result in the elimination of the white pine working group as a viable source of sawlog material. In many areas, harvesting systems which give priority to creating favourable conditions for the establishment and development of regeneration are used. There are still areas, however, where regeneration takes a back seat to the economics of harvest.

Although there are examples of white pine being managed under virtually any silvicultural system imaginable, the two primary systems of management used currently are clearcutting with seed trees and uniform shelterwood.

The system of clearcutting with seed trees is used where a low cost, extensive form of silviculture is desired. Between 5 to 15 seed trees are left per acre as a seed source and best results are obtained when harvesting and occasionally supplementary site preparation occur during a good seed year. The problems of hardwood competition and white pine weevil damage usually results in the success of regeneration being sporadic and the requirements for following tending being high. In the recent revision of the Agricultural Handbook "Silvicultural Systems for the Major Forest Types of the United States", it was stated that for white pine "... the seed tree method has little to recommend it." Other than the facts that it provides little constraint to harvesting and is inexpensive to implement the same can be said in Ontario.

The uniform shelterwood system has within the last decade become the preferred system for managing the extensive areas of second growth white pine. Although it is more difficult and expensive to implement it has the dual advantage of retarding the development of competing intolerant hardwoods and protecting the developing regeneration from weevil attacks by maintaining overhead shade.

The uniform shelterwood system is applied primarily in two ways. The first method is a two cut shelterwood. Under this system basically mature stands are harvested to remove approximately 60% of the crown cover leaving a residual stand comprised mainly of dominant or codominant trees. This harvest is followed up in some cases with light mechanical site preparation, designed mainly to provide an improved seedbed by mixing mineral soil with the overlying humus layer. The removal cut of the residual stand takes place 10-15 years later depending upon the regeneration development. Where adequate regeneration is not achieved, additional site preparation and/or seeding or planting may be undertaken.

The second method of uniform shelterwood management which is used is the four cut uniform shelterwood. Since the primary objective of our management is to produce high quality products we are growing white pine to a large size on relatively long rotations of up to 140 years. This makes the application of at least four commercial cuts during a rotation feasible and in fact desirable.

Aside from early non commercial thinnings which may be applied, the first cut is made when the stands are between 61 to 80 years of age. This cut is a preparatory cut which removes defective or diseased trees and releases the dominant and codominant trees in order to increase their crown size. The increased crown size is necessary so they can better fill the role of seed producer and site protector which will be required of them in the future.

The second cut, a seeding cut, is applied when the stands are between the ages of 81 to 100 years. The purpose of this cut is to create the optimum light conditions on the ground for the germination and development of white pine seedlings together with the control of white pine weevil. Good quality dominant trees are retained at a spacing of 1/2 crown diameter between crowns of adjacent trees. In other words, two trees with 20 foot diameter crowns would be left with 10 feet between their crowns. This provides an average of 38% vertical ground cover and 50% shade on ground.

On dry outwash deposits where pine regeneration is often present before cutting this has resulted in a very high degree of regeneration success. On moister and more fertile sites, these seeding cuts are sometimes followed by supplementary site preparation to control competing vegetation and planting to establish an acceptable stocking level of regeneration.

Under this level of overstory weevil damage is controlled to levels of less than 10% while the development of pine regeneration is at very acceptable levels. The height development of planted bareroot seedlings 3 years after planting is regularly up to 18 inches per year and as high as 30 to 36 inches per year.

The third cut of the series takes place 20 years following the seeding cut. By this time the stands are between 101 - 120 years of age and, depending upon when the regeneration established, the understory is approximately 15-20 years old. This cut is intended to release the developing regeneration while still maintaining 50% shade on ground to provide continuing weevil protection. The trees retained in the third cut are again good quality dominants.

The fourth and final cut which removes the overstory takes place 20 years later when the overstory is between 121 to 140 years of age and the understory is 35 to 40 years of age. At this age the understory no longer requires protection from white pine weevil and the residual trees which have been released by three cuts over the preceding 60 years should be of high value and removal should be possible with a minimum of damage to the new stand.

Employing a system such as this which requires the existing stand to be maintained for an additional 60 years would not be possible if we were starting with a mature stand. In Central Ontario, however, the "sins" of the lumber barons of the past have left us with a white pine forest of which more than 80% is between 60 and 100 years old and this has represented a resource to be worked with rather than liquidated.

The title of this symposium is Eastern White Pine: Today and Tomorrow. This paper has so far discussed white pine management in Ontario yesterday and today but what does tomorrow hold? In 1984, because of the historical significance of white pine, it was established as Ontario's arboreal emblem. Unfortunately, past glories do not guarantee continued prominence. The white pine growing stock in Ontario is dwindling. Many stands of white pine and perhaps even more significantly the white pine component of other working groups is being liquidated. To date, the regeneration of white pine in mixed-wood situations has been virtually non-existent.

The planting of white pine in Ontario has been increasing in recent years. In 1978 2.4 million white pine seedlings were produced in Ontario nurseries. In 1984 the seedling production reached 8 million which is 10% of the total bare root nursery stock production in the province. Some of the planting, however, is being done to supplement regeneration in shelterwood cuts so not all of it is adding productive white pine area to replace that which is liquidated.

We are too often guilty of prescribing harvesting methods rather than silvicultural systems. Especially on the moister more fertile sites where competition is a problem, silvicultural tools such as pre-cut prescribed fire must be made use of on a more regular basis. The success of fire as part of a treatment regime in which harvesting is another important component, has been aptly demonstrated at the Petawawa National Forestry Institute at Chalk River, Ontario and merits a more operational application.

Herbicides have been used to try and solve some of the competition problems we have by chemically releasing natural or artificial regeneration. These competition problems were often of our own making. We must put more emphasis on controlling competition before it becomes a problem by using herbicides as a site preparation rather than a tending tool.

Most of all, we must acknowledge the fact that there is a need to devote the increased time, effort and money necessary to manage eastern white pine. The demand for white pine lumber has been one of the most constant of all forest products over the years and there are a number of secondary manufacturing industries which utilize eastern white pine almost exclusively. The supply, however, is dwindling and since white pine is a relatively small component of the total harvest when compared to the boreal species of black spruce and jack pine, a relatively small effort has been put into reversing the trend. With a commitment of resources such as has been applied to other commercially important species in the past, however, we can assure the continuation of the contribution which white pine has made to the economy of Ontario.

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ECONOMICS OF HEAVY THINNING IN EASTERN WHITE PINE PLANTATIONS[1]

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Abstract

The financial tools on which the analysis of different thinning intensities rest are succinctly presented and then applied to three management regimes tested in managing two stands of white pine (Pinus strobus) in central Massachusetts. The financial analysis shows that a very heavy thinning (16% of full-stocking) alternative presents a slightly higher NPW than no thinning or a moderate thinning (33% of full-stocking) on a good site (site index 80). On a poorer site (site index 75), the two thinning regimes have a similar NPW which is substantially higher than the no-thinning alternative.

Introduction

During Colonial times and continuing to the present eastern white pine (Pinus strobus L.) has been one of the most important commercial tree species in New England. It accounts for about 20 percent of the board-foot volume in Maine, Massachusetts and New Hampshire (Leak et al. 1970). Although its economic importance has diminished in recent years because of the dominance of softwood lumber from other regions and the generally poor quality available, this species still has an important role in the lumber industry in the Northeast for construction and furniture products.

While white pine naturally occurs mostly in mixed stands, nearly pure stands are common from old-field succession on abandoned fields and on dry, sandy soils. Many plantations were established in the first half of this century. In many of these stands intensive management, particularly thinning, is desirable to improve quality and shorten rotations. What intensity of thinning is most appropriate for maximum return will depend on many factors. In this paper we discuss the financial methodology necessary to determine that optimum intensity of thinning. This methodology is then used to analyze the results of a study initiated in 1962 of two intensities of thinning in two white pine plantations by the Department of Forestry and Wildlife Management, University of Massachusetts in cooperation with the Metropolitan District Commission (Hunt and Mader, 1970). The results of the financial analysis are then discussed in the light of the uncertainty surrounding the silvicultural investment.

Plantation Thinning

For most plantations of forest trees, thinning is synonymous with forest management. Thinning permits taking full advantage of the site's annual productive capacity by insuring the best spacing through time to minimize losses to mortality and maximize growth of crop trees. Thinning controls openings in the forest canopy and allows maximum exploitation of the soil nutritional value. In over-stocked stands, trees may stagnate or their growth may be reduced by competition, and they may eventually die, causing loss of accumulated growth.

Figure 1 indicates a current net annual increment, CAI, peaking at age t* which corresponds to the inflection point of the yield function V for an unmanaged stand as in the control plot for this experiment. The forester through thinnings hopes to sustain this high current net growth for as long as it is economically feasible. The economic feasibility analysis follows. The first and second thinnings (there have been only two thinnings in our experiment, but at two different intensities) are expected to maintain that maximum rate of growth up to time t**. The yield for the thinned stand is depicted by V'. Two possible cumulative production functions are depicted by V"A and V"B. The first cumulative volume is almost identical to the yield or production function of the

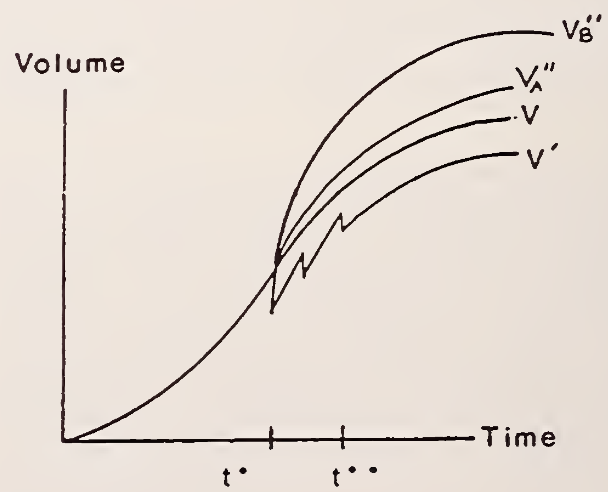

Figure 1. A production function for repeated thinnings.

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unmanaged stand while V"B is well above the cumulative volume V obtained in the control plot. As we will see, a situation comparable to V"A develops on the best site of the experiment where the difference in volume between the unthinned and the thinned plots is negligible. On the poorer site, however, the thinned plots show a higher cumulative volume similar to V"B.

Several advantages are derived from thinning a stand. First the accumulated growth on thinned trees is not lost to mortality. Second, the time of harvest is usually shortened, but not always. If the rotation is lengthened and the maximum CAI maintained through the thinning operations, regeneration costs, such as site preparation and planting, occur less often for the same volume produced. However, the volume should be of higher quality (Hyde 1980). Finally, the total merchantable volume produced may be greater with thinning than without.

The example used in Figure 1 assumes that no thinnings are needed in the earliest years of production when spacing is not a constraint on growth as is reasonable to expect in the case of a plantation for which near-optimum spacing has been used. In the mixed stands of New England, however, there commonly is dense regeneration requiring early thinnings of unmerchantable size or quality, i.e., precommercial thinnings. In this study, both thinnings were precommercial because there was no market in Massachusetts for small diameter trees but only a sawlog market for which a minimum diameter of 8 inches and at least one 10-16 feet long log to a 6 inch top is necessary.

Economics of Thinning

Two basic financial tools are useful in resolving most decisions related to silvicultural prescriptions: marginal analysis and cash flow analysis. Marginal analysis indicates the point at which inputs into the thinning activity just equal the value of the increased growth increment and/or the value of the higher quality growth. Cash flow analysis allows comparison of marginal costs and benefits accruing at different points in time by appropriate discounting and aggregation over a rotation or several rotation periods.

Ideally, the marginal analysis should cover the complete range of inputs over which increment in growth is expected to be optimal. The optimal intensity of thinning is defined as the point where the marginal cost of the operation equals the marginal expected revenue from the operation. In practice, to measure the complete relevant range of inputs for various thinning levels would be unduly costly and time consuming. Usually only a simplified with-without analysis integrating the marginal and cash flow analyses is used. Several mutually exclusive investment alternatives are compared, in this case, several different thinning regimes. In this study three levels of thinning intensity have been examined: no thinning, moderate thinning, and very heavy (low density) thinning. These three mutually exclusive investments are compared using a net present worth (NPW) criterion. The best alternative is the one showing the highest NPW. If the alternatives required different rotation ages, the soil expectation value (SEV) criterion should be used to place the variations in project duration on a common time scale.

Three Management Regimes for an Eastern White Pine Plantation

The plantations of Pinus strobus L. on the Quabbin watershed were established in 1940 on different sites: one was a SI_{50} 80 Woodbridge - very stony loam, and the other a SI_{50} 75 - similar but less stony loam. The land slopes gently (3-5%) to the north and the soils are moderately well drained. Annual precipitation averages 45 inches, with the number of frost-free days between 100 and 165 ($\bar{x}$ = 140) and an average temperature of 69°F.

Three management regimes were tested on the two different sites - no thinning, very heavy thinning and moderate thinning - resulting in the number of trees over time and final mean stand diameter per 0.1 acre plots reported in Table 1.

The final volume and MAI on a per acre basis resulting from the 6 management regimes defined in Table 1 are presented in Table 2 and provide an estimate of the benefits for the different alternatives.

The volumes on the heavily thinned (HT), moderately thinned (MT), and unthinned (NT) plots are practically identical on site 80, indicating relatively equal utilization of growing space with respect to volume growth across a wide range of stocking, from 16% of full-stocking on the very heavily thinned plot to full stocking on the control plot where no thinnings took place. The moderately thinned plot, in which the stocking guide for eastern white pine by Philbrook et al. (1973) has been used, shows the best response on the poorer site, but no difference on the good site. The high mean stand diameter and growth percent for the moderately thinned plot on the poorer site is a result of reduction in number of stems from 29 to 15 due to storm damage in the winter of 1973-74. The 14 smallest trees were severely damaged and cut.

The regression equation developed by Leak et al. (1970) for predicting yields of untreated white pine stands in Massachusetts gives very similar volumes (SI80: 23,387 bd. ft. and SI75: 18,960 bd. ft.) to the actual volumes measured in 1982 on the unthinned plots (see NT in Table 2).

Measurements from the plots on both sites suggest that on very good sites, board-foot volume growth is not necessarily depressed as a result of under- or overstocking. More detailed discussion of the results of this study can be

found in Hunt (1968), Hunt and Mader (1970) and Stone (1985).

Financial Analyses of The Three Management Regimes

The physical inputs and outputs for the thinning study described earlier served as a basis for estimation of the costs and benefits of the three management regimes on the two sites.

Based on the input-output information and using the prices of the inputs and outputs adjusted to 1982 values based on the consumer price index (CPI) for the Boston Metropolitan area, we obtained the cash flow tables for all the management regimes as summarized in Table 3.

The NPW and internal rate of return (IRR) for the six different cash flows are given in the Table 3. Based on these analyses the best of the three mutually exclusive management regimes on site 80 is the one with the highest NPW using a 4% real alternative rate of return (ARR), i.e., the heavy thinning alternative. The second best alternative for site 80 is the no thinning alternative although if the ARR drops below 1% the NPW of the moderate thinning would be higher. The reason for this result is lack of markets for small diameter trees. If there were a market, the moderately thinned management regime would be the second best alternative. Such a market would also benefit the heavy thinning option. With a commercial instead of a precommercial thinning, the heavy thinning option would have a higher NPW than \$194.70. This best alternative has to be selected for the budgeting process, where the ranking of the independent projects is made using the IRR of 5.38.

On site 75, the two thinning alternatives are almost equivalent and bring a much higher NPW than for the unthinned plot. The moderate thinning is slightly better than the heavy thinning but with a market for small diameter trees the opposite ranking would be expected. The early high benefits of the heavy thinning will offset more of the thinning costs or may even produce a benefit from the thinning operation. Both thinnings have an IRR of about 4.17%.

It should be pointed out that the best of the three alternatives tested for each site is probably not the optimal thinning regime from a financial point of view. A more detailed analysis involving more than three points on the production function given in Figure 1 would be necessary to determine the optimal regime. However, the experiment encompassses the more extreme alternatives, ranging from full-stocking to only 16% of full stocking, and also includes the one most frequently followed in New England based on the Philbrook et al. (1973) stocking guide. Consequently, the results of the economic analysis are instructive: more conservative thinnings are more profitable on lower sites.

Uncertainty in Relation to the Financial Analysis

The cash flows are considered less uncertain in this case than for other forestry investment appraisals because the analysis is made in an ex-post fashion. However, extrapolations from this study to other cases has to be made with care. In addition to all the possible differences related to sites and the specific treatments of the experiment, e.g., 13 crop trees/plot were pruned, variation in yields, and price of input and outputs can change the results of the financial analysis. The most sensitive variable is the price of the output, i.e., the logs harvested. A time series analysis of white pine stumpage and lumber made at the University of Massachusetts shows (Harou et al. 1983) that the price has been very stable for the last three decades. This situation could change but a price increase seems more plausible than otherwise. Higher possible revenue would be favored by the fact that the precommercial thinnings could become commercial in the future and offset part or all of the thinning costs. On the other hand, change in technology, e.g., use of smaller diameter logs, may favor lighter thinning or even no thinning at all depending on the sites.

Our analyses do not include different risk considerations related to the intensity of the thinnings that were compared. The heavier thinning seemed to reduce the risk of severe damage from insect or disease attack. At the same time, too wide openings may make the recently thinned stands more susceptible to wind and ice damage. In our studies, the difference in number of trees between 1967 and 1982 was mostly related to ice damage, no blowdowns were observed.

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Table 1. Number of trees removed per management regimes per .1 acre, and the 1972-1982 Mean Standard Diameters and growth

	Number of Trees					1972	1982			
	1940	1962		1967						
	initial	before cutting	after cutting	before cutting	after cutting	MSD (in.)	Total # of trees	merchantable # of trees	MSD (in.)	growth (%)
Site 80										
N T	174[1]	85	85	69	69	8.1	45	34	9.8	21
H T	174	88	13	12	10	13.1	10	10	16.9	29
M T	174	96	48	48	28	9.5	20	20	12.4	30.5
Site 75[2]										
N T	174			69	69	7.3	48	24	8.9	21.9
H T	174		13	13	10	11.5	10	10	15.2	32.2
M T	174		48	48	29	8.2	15	15	13.5	62.2

[1] 3-0 seedlings, spacing 5' X 5' / .1 acre.

[2] Complete records for plantation on site 75 was not available. For the financial analysis the missing data are assumed to be similar to 80.

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Table 2. Final Volume and MAI in 1982

	Volume (b.f./acre)	MAI (b.f./acre)
Site 80		
N T	25,187	560
H T	25,674	570
M T	25,685	571
Site 75		
N T	18,935	421
H T	19,858	441
M T	22,449	499

Table 3. Cash flows for one acre of the three management regimes on the Sites 80 and 75

Cost/Benefit	Year	Site 80 N T	Site 80 H T	Site 80 M T
Cost				
- establishment[1]	0 (1940)		128.78	
- pruning[2]	22 (1962)		96.20	
- precommercial thinning	27 (1967)		35.66	35.66
- marking[3] administration timber sale	42 (1982)			
Benefits				
- timber sale[4]	42 (1982)	1211.00	1802.00	1305.00
NPW ($)		150.50	194.70	99.30
IRR (%)		4.45	5.38	4.28

Cost/Benefit	Year	Site 75 N T	Site 75 H T	Site 75 M T
Cost				
- establishment[1]	0 (1940)			
- pruning[2]	22 (1962)			
- precommercial thinning	27 (1967)		35.66	35.66
- marking[3] administration timber sale	42 (1982)			
Benefits				
- timber sale[4]	42 (1982)	913.25	1218.70	1242.50
NPW ($)		(102.00)	54.60	60.00
IRR (%)		3.65	4.16	4.17

[1] Establishment costs included planting ($8.00/1000 in 1940) and seedlings ($4.00/1000 in 1940). Source: Metropolitan District Commission (MDC).

[2] Pruning cost $.25/tree (Hunt 1961) ($.74 in 82 dollars) 13 trees pruned / 0.1 acre plot.

[3] Cost of marking and administering timber sale is $6.29/woodlot (Kronrad et al. 1980).

[4] Stumpage estimates from MDC records per thousand board feet (based on diameter and quality: $48.08 [N T, 80], $50.81 [M T, 80], $70.19 [H T, 80], $48.28 [N T, 75), $55.35 [M T, 75], $61.37 [H T, 75]).

ROLE OF TREE IMPROVEMENT IN PROVIDING PEST-RESISTANT EASTERN WHITE PINE (PINUS STROBUS L.)

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Three of the major problems of eastern white pine (Pinus strobus L.) are blister rust (Cronartium ribicola Fisch.), white-pine weevil (Pissodes strobi [Peck]), and atmospheric pollution. Suggestions given for developing resistance to these problems include improvement of eastern white pine, hybridization between eastern white pine and other resistant 5-needle pines, and the possible introduction of non-native white pines in the Northeast.

Eastern white pine (Pinus strobus L.), the most important and most neglected tree in the Northeast, occupies nearly 7 million acres in this region, and equally large areas in the Lake States and other areas south along the Appalachian Mountains to Georgia. The native range in Southeastern Canada stretches from Newfoundland to Manitoba and probably encompasses as much area as it does in the United States. The early history of this country is closely tied to white pine. In 1605, Captain Weymouth was sending logs of this species back to England to be used as ship masts. Today nearly every New England town has a Mast Road to remind us. The first sawmill in America was established in 1623 in Berwick, Maine, to saw white pine. For more than 300 years (1605 to 1910) eastern white pine was the most important timber species in the United States. Although the harvest volume of other species now exceeds white pine, it is still in high demand because of its unequalled qualities.

There are more diseases and insects associated with eastern white pine than with any other species of tree in North America. The survival, growth, and form of white pine also are affected by fire--especially in young stands with thin bark--deer, rabbits, squirrels, mice, porcupines, and grosbeaks. And white pine is intolerant to drought and flooding, sulfur dioxide, ozone, stack gases from coal-burning plants, fluorine, and radiation. Among conifers it is the most sensitive to salt sea spray and probably road salts. While all of these factors produce a degree of injury up to and including the death of the tree, with few exceptions, little has been done to prevent damage specifically on eastern white pine. Some research in the South with Fomes annosus (Cronartium quercuum f. sp. fusiforme) and some of the work with insects and diseases in other parts of the country might be applicable to white pine.

I will discuss the problems and opportunities for pest resistance in eastern white pine through selection, breeding, or both. Pests of this species range from moose to mice; white pine also is attacked by a large number of insects, an equally large number of diseases, and some things that we cannot see except in the response of the tree. I will exclude the birds and animals that are known to damage white pine only because such damage usually is minimal or spotty and not because resistance might not be found if we looked.

The Australians have identified trees with high levels of salicin, the main ingredient of aspirin, that repels feeding by opossum. Similar chemicals in white pine might discourage feeding by ruminants and rodents. That brings us to the three major causes of damage to this species: (1) diseases, (2) insects, and (3) atmospheric pollutants. These can produce severe damage alone or in combination.

In preparing this report, I reviewed hundreds of articles that discussed resistance in eastern white pine, other soft pines, hard pines, and work with other genera that had direct application to the 5-needle pines. In the bibliography of this report, which represents only a fraction of the literature on the subject, I have limited the selections to those pertaining to one disease, one insect, and three atmospheric pollutants. The disease is blister rust (Cronartium ribicola J.C. Fisch. ex. Rabenh), which probably is not serious in the Northeast at this time but may be more serious in the Lake States. It is clearly the most serious problem affecting white pine in the West. The insect is the white pine weevil, (Pissodes strobi Peck.), a serious pest in the Northeastern United States and Southeastern Canada but less serious in the southern and western portions of the natural range of eastern white pine. The atmospheric pollutants are sulfur dioxide, ozone, and nitrous oxides--alone and in combination.

Blister Rust: History and Problems.

Diseases always have been serious in the white pines. Dana (1956) discussed the colonial period of this country and the ship mast industry of that time. One record indicated that 102 of 106 large trees cut for that purpose had so much decay that they had to

be discarded. We can only speculate as to what diseases were present in the year 1600, but we do know that the most serious disease of white pine today had not yet arrived on our shores.

The gene center of all white pines was in north central Asia, which, not surprisingly, also is the center of the rusts associated with these pines. As the pines migrated outward from that area, they carried rust with them. The section strobus spread to North America and the section cembra moved south into Asia and southern Europe. The original blister rust also differentiated into Cronartium occidentalis Hedge in North America and C. ribicola Fisch. in Asia. The species that co-evolved with these rusts apparently suffered little damage from them (Leppik 1970). Then, starting about 1860, the natural order of things began to fall apart rapidly. Cronartium ribicola was transported 1,500 miles from the native range of Pinus sibirica to the range of P. cembra and P. peuce on a shipment of infected ornamental stock destined for botanical gardens. By the late 1800's, it had moved another 2,000 miles from European Russia to Great Britian on both Ribes and P. strobus planting stock. In 1892, with man's intervention, it took another giant step and crossed the Atlantic Ocean on a shipment of P. strobus from France to Kansas. About that same time, Canada imported P. strobus seedlings from Germany to reforest some old agricultural lands in Ontario and the rust came with it (Zsuffa 1981). By 1910, rust had crossed this continent and infected P. monticola; less than 20 years later, it had spread southward on that species and P. lambertiana until all white pines in the United States and Canada were exposed (Spaulding 1956; Bingham and Gremmen 1971).

In the Northeast, in areas where rust was severe, 94 percent of trees in some stands were cankered (Hirt 1948). In western white pine,where the problem is still critical, we probably will lose 90 to 95 percent of the original population. While the monetary losses are substantial, the attendant loss of a major portion of the genetic variability for growth, pest resistance, and all other important traits is even more significant and permanent (Bingham and Gremmen 1971). Except in localized situations, the problem in eastern white pine and sugar pine never was serious because trees grew on fairly extensive low-rust hazard areas. The seriousness of this disease was quickly apparent and efforts were made to stop the spread and minimize the damage. The first program to control blister rust began in 1909 and quickly expanded into the largest tree disease control program ever undertaken before being superseded in the mid-1950's by other control measures (Anderson 1973). More than $100 million was spent to eradicate the alternate host (Ribes) in the United States, but we still lost 650 million board feet to this disease in 1952 alone.

As early as 1927, people in the Northeast were observing what they called "clean trees," those that showed no symptoms in areas of heavy rust (Hirt 1948). Some of these trees were inoculated artificially to determine whether they were resistant or escapes. The major programs at the University of Wisconsin (Riker 1945) and in Ontario, Canada (Heimburger 1958) began in 1937-38. In 1949, the Quetico-Superior Wilderness Research Center in Ely, Minnesota, borrowed material from Wisconsin and then added 400 to 500 selections from the Superior National Forest to their program (Ahlgren 1967). Work with western white pine began in 1949 (Bingham et al. 1953; Bingham 1966). In all of these programs, seed was collected from 'clean trees' and grown in a nursery interplanted with Ribes or sprinkled with Cronartium-infected leaves of Ribes. Those seedlings that survived the "natural" inoculations were later inoculated artificially one or more times.

While the individual-tree selection and testing was taking place, other studies were begun to see if entire progenies or even provenances were resistant to blister rust. Scholz (1960) reported provenance resistance for eastern white pine in an experiment in Germany, but everyone else working on this problem reported that progeny and provenance resistance of eastern and western white pine does not exist (Vloten 1941; Riker 1943; Bingham 1969b; Heimburger 1962).

One of the problems in selecting individual trees in the wild is that in addition to having to screen so many trees that may be escapes to find the few that actually contain some level of resistance, we still do not know enough about this rust or how trees respond to infection. The preponderance of literature on this subject indicates that there are at least two virulent races of blister rust and possibly a third that modifies the actions of the other two (Hoff and McDonald 1971, McDonald and Hoff 1975). There is evidence that pine needles exhibit differential resistance to the virulent races but Anderson and French (1955) found no evidence that these vary in pathogenicity on pines. Just the presence of more than one race, and the potential for the development of additional races over time, is a complicating factor in developing resistance in a tree species.

Resistance mechanisms in P. strobus have not been studied as thoroughly as those in P. monticola, and most of the conclusions are based on indirect evidence. On the basis of the response of progeny tests of P. strobus to artifical inoculation, Heimburger concluded that there were no major genes for resistance

and suggested polygenic control (Zsuffa 1981). Resistance in P. lambertiana is simply inherited from a single dominant gene (Kinloch and Littlefield 1977), while at least two heritable traits are present in P. monticola, each controlled by a single recessive gene. One gene controls premature shedding of infected needles and the second controls infection even though infected needles remain attached to the tree. Growth of the rust mycelium in the needle proceeds normally until the hyphae reach the short shoot. At that point, a resistance mechasnism is triggered that causes host-cell necrosis and fungal death. Normal canker development is prevented and the stem remains disease free (Hoff and McDonald 1971). There also is evidence that extracts of foliage of P. monticola contain compounds inhibitory to blister rust, and that the presence or absence and/or levels of these compounds are inherited (Hoff 1970).

Not all resistance mechanisms are so absolute. While it is true that the systems described result in the elimination of rust, other more complex systems produce a tolerance-type reaction. One such reaction is higher survival of cankered seedlings. Being able to remain alive though cankered is an important trait which allows the fungus to continue the life cycle, thus decreasing selection pressure for new races (Hoff 1984).

The most important concern for a tree breeder is whether the resistance he finds or develops will be long term or permanent. In agriculture, the breakdown resistance with the appearence of new strains of a pathogen is a common phenomenon. In wheat, a variety that has not lost its resistance after 10 years is considered a super variety because it produced nine good crops before it has to be replaced. At CIMMYT, the economic life span of wheat varieties is 5 years. In forestry, the longevity of the tree and the length of the breeding cycle for most species are a real concern. Five or even ten years are only a fraction of one rotation. Impermanence usually is associated with monogenic inherited resistance while polygenic inherited resistance, which often does not give complete protection, is more permanent (Heybroek 1969; Heimburger 1961).

Vertical resistance tends to be self-defeating, especially in long-term crops such as trees, because it imposes intense selection pressures that favor new or previously unimportant races of a pathogen (Borlaug 1965). In agriculture, commercial seed companies generally look for vertical resistance, uniform stalk height, time of ripening for ease in harvesting, and other traits that will maximize harvest and reduce costs; but they can switch varieties every few years if problems develop. Foresters do not enjoy that luxury. Since the resistance to blister rust in P. strobus is polygenic, several generations of breeding probably would be needed to bring the proportion of resistant progeny to practical levels. However, once that was achieved, the resistance would be fairly stable and more difficult to overcome by new races of the pathogen (Steinhoff 1971; Anderson 1973).

As with other programs working with disease resistance, there is a problem correlating laboratory resistance levels with those observed under field conditions (Riker et al. 1943). Resistance is a threshold character that can be overcome with artificial inoculation under ideal conditions (Bingham 1966), and one can suspect that field levels of resistance will differ from those observed in the laboratory or nursery (Zsuffa 1981). Another problem is that resistance will appear low in most tests because trees are inoculated when they are most susceptible--in the seedling stage. As trees mature, resistance will appear to increase so that the actual percentage of trees remaining healthy under natural inoculation loads in the field will be greater than indicated by tests, conditions under which they were inoculated and age both being a factor (Heimburger 1950a; Patton 1961; Bingham et al. 1969). There is a good chance that we will never produce a completely immune white pine, but we probably can produce one that will survive field-level inoculations.

Another partial solution to the problem in the East might be the avoidance of high-rust hazard areas. That may not help the small landowner, who has no choice of sites, but large landowners, i.e., states, national forests, and some of the larger landholders might be able to use this method. The spread of blister rust is favored by extended periods of moderate temperatures (below 67°F) and the presence of free moisture (dew) on needle surfaces during late summer and early fall when the teliospores form on Ribes leaves. Small differences in local climate can greatly influence the amount of infection (Anderson 1973). In low-hazard areas, control of Ribes probably was never justified, and there are hazard maps available for the Northeast now (Charlton 1963). South along the Applachians blister rust becomes more important at the higher elevations where native Ribes are more abundant (Powers 1966). Special attention to microclimate might be advisable above 900 feet in that region.

Chemical control with antibiotics was attempted in the early 1960's, but this effort was largely abandoned as ineffective. Acti-dione (cycloheximide) and Phytoactin were absorbed and translocated when applied from the air or as a basal spray, but neither was effective (Ahlgren 1965; Anderson 1973). Quick

and Lamoureaux (1967) inoculated with Tuberculina maxima, a purple mold that is a hyperparasite on blister rust.They achieved partial control of the canker inoculated. Unfortunately, T. maxima does not spread from the point of inoculation, so it was not effective on other cankers on the same tree or on surrounding trees in the same stand. Gremmen and deKam (1970) controlled rust in nurseries in the Netherlands when they sprayed 10 times each season with 0.5 percent Maneb. This is an expensive operation and they again suggested that seedlings exposed in the nursery that are free of infection when shipped to the field likely will survive the much lower field-level inoculations.

There is no question that planting North American white pines, particularly P. strobus, in many other parts of the world (including a number of developing countries) has been slowed or halted temporarily due to the rust problem. Radu (1981) listed a number of central European countries where rust is a limiting factor; yet he recommended planting because of the value of P. strobus. Schmitt (1971), working in the Hesse region of West Germany and Austria where much of the planting of this species occurs, stated that "...no European forest tree will bring a higher yield on any site;" and Saho (1969) indicated that P. strobus remains the prefered white pine introduction in Japan despite rust.

There is some hope. There are now three seed orchards in Idaho that can produce enough resistant (65 percent of the progeny) P. monticola seedlings to plant 20,000 acres each year (Kingsbury 1984). And the USDA Forest Service has developed several small seed orchards in the Lake States to produce resistant P. strobus. Because the problem is less severe in the East, there has been less emphasis on developing rust resistance, but this should receive more consideration due to the worldwide interest in planting this species.

White Pine Weevil: History and Problems

The major deterrent to planting P. strobus in the Northeastern United States and Southeastern Canada is the white-pine weevil. The weevil is an indigenous pest that we can not blame on anyone else; and despite the fact that it was here to greet the first people who walked across the Bering Strait, we still do not have an adequate or acceptable method of control.

Weeviling probably was responsible for the poor form that caused the Crown to search so hard for straight white pine in the 1600's. The total loss of potential timber volume to the weevil in New Hampshire alone was estimated at 2.2 billion board feet of sawlogs and 151 million cubic feet of other materials through 1955 (Waters et al. 1955). In New England and the Middle Atlantic States, the average annual loss is estimated at 120 million board feet of sawlogs and 31 million cubic feet of other materials (Marty and Mott 1964). As early as 1927, Peirson said that this was the most serious enemy of white pine in the Northeast. Zsuffa (1981) stated that the weevil poses the greatest threat to Ontario's white pine plantations. Interest still is great in the Province and planting of this species has been increasing, though genetically improved varieties are required to ensure plantation success.

Because white pines growing under hardwood overstories had less apparent weevil damage, early suggestions for control advocated close spacing, underplanting, cutting weeviled tops, and even knocking weevils off the trees and into nets. Close spacing and underplanting slow the growth so much that they generally are counterproductive (Fig. 1). Due to the rapid movement of weevils into "weevil-free" areas, physically removing the insects would not be practical.

The next round of studies involved chemical control by both aerial application and leader drench from the ground. DDT and Lindane were the principal materials tested and both were effective when applied properly. Stotz (1960) still was advocating the use of insecticides in Pennsylvania in 1960, but since that time the use of these two chemicals has been banned. DDT has been banned permanently, but Lindane has been on and off the list in the past few years. Marty and Mott (1964) proposed the use of biotic control--viruses, bacteria, protozoa, fungi, genetic manipulation of the weevil, and sterilization of male weevils based on the success with the screwworm in the South. The success of sterilization depends on factors such as the ratio of sterilized to normal males and the success of sterilized males in competing with normal males in fertilizing females. We knew nothing about populations then or now, and none of these ideas was pursued.

Emphasis shifted from the insect to the tree in the early 1960's when interest at the Hamden Laboratory switched from weevils to gypsy moths and the Genetics Project at Durham took over the white pine program. The Genetics group had established a large number of provenance plantings of P. strobus throughout the range of the species in 1959-60. These plantings contained provenances from the entire range, including several of the outlier populations in the Central States. We had material in these plantings that was in replicated designs and on uniform sites. Trees were of the same age, had been grown at uniform spacings, and had been exposed to

uniform weevil attack. The first thing that geneticists always do is look for source differences.

Wright and Gabriel (1959) observed less weeviling in Ontario sources than in those from New York, but concluded that locating local races resistant to weeviling would be difficult. Cage testing by Connola (1973) indicated a lack of weevil resistance regardless of seed origin; he was convinced that his studies disproved the existence of geographic provenances of weevil resistant white pines. Garrett (1972, 1973) measured weevil damage in provenance plantings in southern Maine and in southern Ontario. The Maine planting had been sprayed with Lindane for the first 10 years and there was no weevil damage during that period. Two years after the spraying program was terminated, weeviling by provenance ranged from 71 to 100 percent. Only 3 of 27 sources had leader damage below 80 percent; 12 had more than 90 percent and 4 had 100 percent. This indicates how quickly weevils can move into a weevil-free area. In the Ontario planting, as in Maine, source differences were significant but all sources were heavily weeviled (81 to 95 percent). The conclusion was that while there are differences, even the lowest levels of attack were unacceptable (Fig. 2). Wilkinson (1983b) recorded the number of attacks over an 11-year period in the same Maine planting. He found sources that had fewer attacks and one, a Massachusetts source, that could be recommended for this area based on a combined score for frequency of attack and growth rate.

In all of our studies and in the cage tests, it was obvious that individual trees either were not attacked at all or responded differently when attacked (Connola 1973, Garrett 1970). A number of studies were initiated to study individual-tree variation. The problem with this insect is that instead of killing the tree it attacks, it merely kills the leader, which produced a bushier top. The bushier top probably produces larger cone crops, which in turn, produce a greater number of susceptible progeny. After thousands of years of coexistence, the only resistance in eastern white pine would be the result of random events that had nothing to do with the insect, or gradual changes that became fixed over time in isolated populations. Bark thickness proved to be an unreliable criterion for separating susceptible from resistant trees (Wilkinson 1983c). Spacing of resin canals in the terminal shoot was a function of leader diameter and was not a useful trait. The resin itself was analyzed for both viscosity and rate of crystallization but neither was of any value in this program (Wilkinson 1979b, Zsuffa 1981).

MacAloney (1930) suggested that the odor from pitch of attacked trees was a strong attraction factor for additional weevils. A Pennsylvania study suggested a similar mechanism that keeps the weevil away or induces them to leave after initial feeding and before eggs are oviposited (Soles et al. 1970). Wilkinson (1980) used gas-liquid chromatography to analyze the monoterpens of 590 _P. strobus_ in the 1960 Maine provenance planting . Eight monoterpenes were identified in the cortical oleoresin of these trees and two differed significantly by category of weevil damage. Limonene concentration was consistently lowest in trees that were unsuccessfully attacked and highest in trees attacked most frequently. Alpha-pinene was highest in successfully attacked trees. It is possible that these two monoterpenes could be useful in indirect selection for weevil resistance; however, this program was never funded adequately to carry it the next step which would have been to determine whether the concentration of these monoterpenes was heritable.

Air Pollution: History and Problems

The effects of atmospheric pollution and deposition on forest trees are more nebulus than the effects of insects and diseases and, with the exception of the occasional Sudbury, have only recently been of general concern. However, the lack of understanding of what might be happening has not restricted the number of conferences and publications on the subject. Many of the recent investigations have involved white pine--and for good reason, _Pinus strobus_ probably is more susceptible to air pollutants than any other tree species in North America.

Damage from the smelters in Sudbury, Ontario, eliminated white pine from a fairly extensive area (Gorham and Gordon 1960). Because of its sensitivity, this species was used as an indicator plant to define the area of pollution by this particular smelter (Linzon 1966; Navratil and McLaughlin 1979). Reports of large-scale damage in North Carolina, Pennsylvania, and Wisconsin also have been reported (Landgraf et al. 1969; Nichols 1972; Prey 1968), and there is every reason to believe that additional damage is occurring. Reports in European literature are increasing rapidly due to increased damage and more awareness (Gartner 1983). An excellect summary of this problem is contained in "Effects of Air Pollution on _Pinus strobus_ L. and Genetic Resistance: A Literature Review" (Gerhold 1977). As in the rust programs, the major problem in working with air pollutants and atmospheric deposition is that in nature we are not working with a closed system that excludes all other substances. And it is difficult to ascribe symptoms to one or even a combination of agents. Another problem is that symptoms

are similar for a number of pollutants and diseases. And the literature contains contradictory and highly speculative reports.

Rhoads et al. (1979) noted that there was little visible damage even when ambient ozone levels exceeded the standard. They concluded that trees were relatively insensitive to this photochemical air pollutant. Nellessen and Skelly (1981) reported that the severity of symptoms on P. strobus was correlated with both chronic and periodic acute levels over time. Davis and Wood (1967) exposed 3-year-old seedlings of 22 tree species to 10 and 25 pphm ozone for 8 hours. They found no visible injury at 10 pphm, but P. strobus was among the species displaying symptoms at 25 pphm. Symptoms on P. strobus show on the needles as light flecks, chlorotic mottle, and tip necrosis. As a result of these foliage symptoms, during the season of exposure there is some evidence that this is expressed the following season in reduced diameter growth (Benoit 1980; Jensen 1980; Jensen and Masters 1975).

There are several factors that seem to affect the sensitivity of P. strobus to ozone. Trimble and Orcutt (1980) found that the alkane content of epicuticular wax differed in sensitive and resistant clones. The higher the concentration, the greater the tolerance. The other major phytotoxic component of photochemical smog is peroxyacetly nitrate (PAN). Young pine seedlings exposed to ozone are damaged, but there is no damage due to PAN alone. When exposed to both ozone and PAN, damage is less than that from ozone alone,indicating an antagonistic response.

Other stress factors on a tree can produce a different response to a given level of a pollutant. Harkov and Brennan (1980) observed that both soil fertility and water stress are important. Intermediate levels of nitrogen resulted in a greater susceptibility while high levels reduced symptoms (Will and Skelly 1974). Water stress, which causes the stomates to close, reduces ozone damage.

Damage directly related to ozone is not the end of the problem. Ohmart and Williams (1979) suggested that the loss in vigor leaves the plant open to attacks by insects that further damage or kill the tree. James et al. (1980) reported that from injury to foliage oxidant air pollution increased susceptibility to colonization by Fomes annosus under both field and chamber environments. Hayes and Skelly (1977) speculated that continued exposure of P. strobus could affect vegetative vigor enough that the trees could not compete with other vegetation, and would be attacked by insects and diseases. Such exposure to ozone also might affect reproductivity. All of these adverse effects could lead to type conversion over time (Berry 1971).

To add to the apparent confusion, Tamm and Cowling (1976) found beneficial effects of airborne substances. Some appear to be beneficial at one time of the year and detrimental at other times; as in other studies, Tamm and Cowling found that resistance is under genetic control. Costonis (1971), Berry (1971), and others have reported that pine species including P. strobus were injured more by ozone than by sulfur dioxide, though the injury observed was so similar that they could not distinguish one from the other. Banfield (1971) and Weidensaul (1979) reported a clear synergistic effect with exposure to a combination of the two gases. Miller (1983) reported an additive effect that was up to 7times that of the gases singly. Mahoney et al. (1981) observed reduced height growth and dry weight with mixed gases (ozone, sulfur dioxide, nitrous oxides), but singly they either increased growth or had no effect. However, Nielsen et al. (1977), found an antagonistic effect that they attributed to stomatal closure in response to the ozone and stomatal opening due to sulfur dioxide.

There are a number of suggestions for screening for resistance to a number of airborne pollutants. Schindlbeck and Braun (1979) used thin-layer chromatography of needle extracts to find fluorescent metabolites associated with resistance to sulfur dioxide,and suggested this as a technique for evaluating resistance in select trees. Bueher-Wallin et al. (1979) found that glycosidases activity in the foliage of different clones of the same species (Picea, Fagus) is influenced by sulfur dioxide levels, and that this could be used as an indicator of latent injury at ambient levels. Krause and Dochinger (1984) found that surface waxes of P. strobus needles had a different arrangement on trees exposed to filtered or nonfiltered air. Krause and Houston (1983) also reported that the epistomatal wax formed a continuous covering over stomata of P. strobus tolerant to sulfur dioxide, but was split longitudinally over stomata of sulfur dioxide sensitive clones. They suggested this as another guide for tolerance. A recent report (Univ. of Illinois 1985) reported that gypsy moths prefer trees "spiced" with ozone. This does not seem to alter the taste, but pollutants may deter plants from producing unsavory chemicals that discourage insect feeding.

One problem associated with air pollutants is post-emergence chronic tipburn. This is serious in P. strobus in the mid-South. The symptoms seem to be associated with abnormal weather conditions (Berry and Ripperton 1963; Amman and Berry 1963) and can be duplicated in chambers with standard air pollutants. Another

problem that is range-wide is chlorotic dwarf disease which occurs on trees as old as 40 years. Although it has been around for 90 years, we still cannot assign a positive cause (Dochinger 1963). Earlier, it was thought that this was a root problem, but later evidence indicated that this was a symptom of air pollutants. The result is a breakdown of chlorophyll, loss of needles, and a reduced supply of photosynthates needed for normal growth of the tree (Dochinger and Bender 1970). The proof was that this harmful action of gases acting on the foliage of susceptible trees could be reversed by using filtered air in chambers (Dochinger et al. 1965). A third problem is semimature tissue needle blight (SNB), which has symptoms similar to those of sulfur dioxide, and with good cause (Linzon 1966). Costonis and Sinclair (1969) saw it as distinct from other symptoms but by 1970, Costonis decided that SNB and sulfur dioxide damage were one and the same.

The good news is that there appears to be genetic variation in resistance to most of the atmospheric pollutants; the bad news is that the bulk of the studies so far have included very young seedlings. As a result, we have not been able to obtain good juvenile-mature correlations. The response at 6 weeks is not the same as at 10 weeks (Davis 1977; Davis and Wood 1972), which makes it difficult to incorporate results from these studies into air quality standards. Also of concern is that in many of these studies there is evidence or speculation that growth loss is occurring in forests subjected to low-level and long-term exposure to air pollutants, and that such a loss is not noticed and/or evaluated (Phillips et al. 1977a, 1977b).).

Solutions: Selection and Breeding

This review of the literature provides some background on three of the major problems of *P. strobus* throughout its range and particularly in the Northeast. In the case of blister rust, there has been some progress in identifying resistant *P. monticola*. Several *P. strobus* have been located that can withstand inoculation, but there has been much less effort in the East to determine if these individuals can pass on the resistance to their progeny. In *P. monticola*, 67 percent of the progeny from orchard trees should be resistant. We do not know what that figure might be from the *P. strobus* orchards in the East and Midwest.

The results of air pollution on *P. strobus* and other species of forest trees are unknown, confusing, or contradictory. In the worst-case situation such as Sudbury, Ontario, there is no question that one or more airborne pollutants were responsible for the death of *P. strobus* in a very large area surrounding the smelter. Where concentrations of pollutants are lower, or where they tend to be intermittent, there are many questions to be answered before industry standards can be established. Reports appear on both antagonistic and synergistic effects on the same species. Symptoms of several pollutants and a number of "diseases" are similar and difficult to distinguish. Effects may be beneficial or detrimental depending on the time of year and age of the seedlings. Correlations between very young seedlings used in most experiments and older trees surrounded by the ambient mixture of gases found in the atmosphere have not been established.

Weeviling is a different problem. We know that there are individuals and even sources that are statistically different in levels of attack or in their response following attack. We do not know whether these are heritable traits that will be passed on to the progeny or whether they are unique to the individuals we are looking at.

Research programs in both the West and the East have focused on three approaches to solving each of these problems. In some cases there is a priority but in others they are handled simultaneously. The first step is to examine existing provenance plantings for source differences . At the same time, we usually can get an indication of possible individual-tree resistance, which can then be pursued to see if the resistance observed is heritable. Another possibility is a hybridization program with native species that may be susceptible to certain pests and other 5-needle white pines that are known or suspected of being resistant. The third approach is the introduction of pest-resistant,non-native white pines. Each of these approaches has some advantages and probably some disadvantages.

While we still are trying to understand the relationship between native populations of *P. strobus* and air pollutants, we do have some indications, that other species and hybrids may contain some resistance that could be used in a hybridization program (Genys and Heggestad 1978). *Pinus parviflora*, *P. cembra*, *P. bungeana*, and *P. cembroides* are reported to be highly resistant to both ozone and sulfur dioxide. *Pinus koraiensis*, *P. armandii*, and *P. wallichiana* are resistant to ozone but susceptible to sulfur dioxide. The hybrid *P. wallichiana* X *P. strobus* is resistant to ozone but susceptible to sulfur dioxide, reflecting the contribution of *P. wallichiana*. All *P. strobus* clones were susceptible to both gases except 'Brigham' (a Maryland collection), which was resistant to ozone, and an Ontario clone (No. 77), which was resistant to sulfur dioxide.

Cornartium ribicola has been with us for almost a century. In that time, many plantings of exotic species have been exposed to this disease in the United States and around the world. In the East, it may be possible to plant P. strobus in low rust-hazard zones without excessive damage; that option may not be available in the Western States. Selection of resistant P. monticola has resulted in the establishment of several seed orchards from which 67 percent of the progeny should be rust free.

Two other options that are available would be the use of exotics of known rust resistance in a hybridization program with our native species, or the introduction of non-native trees as alternate species in areas of extremely high hazard. If we look at a summary of 16 separate reports in the literature, we can see the results of inoculation tests on most of the 5-needle pines and a few hybrid combinations (Fig. 3). Not all of these species would be useful due to poor form, slow growth rates, lack of resistance to other pests, or other adaptation problems. The problem is that we have learned practically nothing about these questions in the 100 years since we first recognized that we had a serious problem with blister rust. With rare exceptions we have not sufficiently tested provenances or progenies of even the most potentially useful 5-needle pines. In many cases, the seed that was used has been of unknown origin and certainly of unselected parents. The few hybrids that have been produced were made from trees in arboreta around the country. Seed for these parent trees may have come from "landscape types" which could be far different from the types we want to include in our reforestation programs. Despite these shortcomings, we still have useful trends that should be investigated. Pinus wallichiana and P. koraiensis in their native ranges are as impressive as any North American white pine, and they exhibit broad site adaptation (Ahsan 1972). Both of these species are resistant to Cronartium ribicola, as are the hybrids between these species and both P. monticola and P. strobus. Pinus wallichiana X P. strobus, the reciprocal cross, and P. strobus X P. ayacahuite may outgrow any of the parents here in the East (Garrett 1979; Wright 1957). While the P. strobus X P. monticola hybrids in earlier tests tended to be highly susceptible to C. ribicola, they have excellent potential in the Northeast and in the West, where they outgrow both parents. The early tests did not contain rust-resistant P. monticola selections that are now available in the seed orchards. Pinus flexilis x P. wallichiana has extremely fast growth for white pine and outgrows P. flexilis by 100 percent.

Weevil damage in plantations of Pinus strobus in the Northeastern United States and southeastern Canada has become a catastrophe of the same proportions as rust damage in the West. Unfortunately, we are not as far along in finding a solution; at present, there is no work underway to solve this problem. What is needed now is a continuation of the work started at Durham along with adequate resources to complete the job. We need to go into those plantings in which we have identified weevil-resistant trees and do controlled crossing of resistant x resistant and susceptible x susceptible individuals to see if this trait is heritable. Trees that survive that test would be the foundation stock for seed orchards in the East.

As with the rust problem, we have other equally desirable alternatives if we are willing to shed some of our parochial thinking. Pinus monticola is weeviled much less than P. strobus and could be used in the Northeast, where weeviling is severe (Heimburger and Sullivan 1972b). Soles et al. (1970) reported about one-fifth as much weeviling on P. monticola as on P. strobus in New York. Garrett (1970) found 22 percent weeviling on grafted P. monticola from Idaho and 18 percent on grafts from a New York planting of this species compared to 60 percent on P. strobus from Maine. Wilkinson (1982) reported only 13 percent as much terminal damage in P. monticola as in P. strobus. Hanover (1975) and others attempted to identify the resistance factors in P. monticola that make them so different from those in P. strobus. The foliage and stem oleoresin chemistry is significantly different. The monoterpenes camphene, B-pinene, limonene, and total monoterpene levels are all different. In addition, 12 of 13 resin acids are different. These results complement those of Wilkinson between resistant and susceptible trees of P. strobus. In addition to the weevil resistance reported by Wilkinson, 4 of 17 families of P. monticola were as tall or taller than P. strobus. This suggests that selection of the proper seed sources would result in plantations with acceptable growth rates and weevil resistance. Progeny trials of P. monticola were established in Maine and New York to locate resistant families; with some roguing, these plantations could provide excellent seed production areas. Provenance plantings and plantings from bulk seed collections of this species were established in the Northeast and Canada at the same time.

Pinus peuce also deserves further study. The resistance factor is not as well understood as it is in P. monticola, but most reports rate it as more resistant than P. strobus (Heimburger 1966, Heimburger and Sullivlan 1972a; Zsuffa 1981; Wright and Gabriel 1959; Kriebel 1982, Connola 1978). In several studies the response varied by source, but selection within the species could resolve that problem. Heimburger and Sullivan (1972a)

reported a high frequency of attack on this species but also a good recovery unlike P. strobus. They also found that damage varied considerably by clone; they found this interesting because of restricted natural range. The total area occupied by P. peuce probably is less than 25 square miles but it is considerably fragmented, which could have produced this variation over time.

Pinus koraiensis and P. armandii have been reported to be weevil resistant (Kriebel 1982; Wright and Gabriel 1959), but more needs to be done with these species. Wright and Gabriel (1959) also reported P. wallichiana to be resistant; and while individual trees might, indeed, be resistant, we have a planting in southern Maine that is much more heavily weeviled than P. strobus check stocks.

We also can use some of these resistant species in a hybridization program with P. strobus to produce weevil-free trees. In 1948, Stockwell reported that P. strobus X P. monticola hybrids were twice as tall and had 3 times the dry weight of the best parents. He suggested that "...the time was ripe for extensive testing and trial planting by those interested in reforestation...." Nothing was done. Wright (1959), Duffield and Righter (1953), and Meyer (1953) reported that P. strobus X P. wallichiana would outgrow P. strobus. Hybrids in Canada were 60 percent better than P. strobus (Zsuffa 1976). There are other species and hybrids that deserve consideration and further research based on growth and/or pest resistance in small studies and plantings. Pinus strobus X P. parviflora hybridization has occurred naturally when these species were grown in the same area, and P. parviflora is a weevil-resistant species (Johnson 1952). Pinus peuce X P. monticola is resistant to weeviling, which could yield weevil and rust-resistance in the same tree if we start with rust resistant P. monticola. Pinus strobus X P. ayacahuite outgrows both parents in the East and P. monticola X P. strobus outgrows the parent species in the West. This combination also is promising in the East because of its weevil resistance (Wright 1957).

Individual species also have considerable promise. Kriebel (1982) and Wright (1957) indicated that Pinus wallichiana grows as fast or faster than P. strobus in the Northeast and is rust resistant. It may not be weevil resistant. Pinus monticola is an excellent candidate, P. koraiensis has produced good early growth, and P. flexilis, which has relatively poor form in its native range, produces some excellent specimens in the Northeast. Kriebel (1982) achieved good growth on P. strobiformis and Heit (1970) reported that this was an excellent tree in New York. Our experience has been that it has extremely rapid juvenile growth and apparently is winter-hardy despite the fact that the natural range covers an area from Latitude 22° N (near Mexico City) to Latitude 37° in New Mexico.

The potential value of hybrids depends not only on their performance but also on the ease of massproduction by seed or vegetative techniques. Crossing studies with a few species have provided indications of potential seed yields. Again, because the observations often are based on the performance of only one or a few trees, the literature is sometimes contradictory. Wright (1959) reported that the potential for P. strobus X P. wallichiana and the reciprocal hybrid was low, while Meyer (1953) claimed that the hybridization of these species produced good seed yields and 82-percent seed viability. Pinus monticola X P. wallichiana and P. monticola X P. strobus produce good seed yields. Another problem is that phenology of species and select individuals in a breeding program may not be synchronized; as a result, orchards containing more than one clone per species may not yield a high percentage of hybrid seed. Orchards of first-generation hybrids may be useful but, again, we know even less about the phenology of these plants, and some researchers have expressed concern about reduced seed set and fertility in hybrids (Heimburger 1963).

With all of the promise of these species and hybrids, we should not be deterred by these unanswered questions; rather, we should be encouraged to get on with the research needed to solve these questions. We already have enough plantings of some non-native species in the Northeast and Canada to make selections of individuals that have proven their adaptability to our climates over many years. There are flowering-age plantings of P. monticola (Heimburger 1966; Wilkinson 1982; King personal correspondence); P. wallichiana (Heimburger 1964; Kriebel 1982; Wright 1957); and P. peuce (Heimburger 1966) that are available now for selection and hybridization. In 1964, Rudolf and Patton expressed concern about the direction of this type of research: "...little or no thought of pursuing the work to its logical conclusion ... requires a great deal more organized and purposefully directed effort than has gone into it in the past...." It is difficult to argue with that statement. If even a fraction of the literature is believable, we are sitting at the edge of an ocean of potentially useful material. Yet we seem afraid to take the plunge.

One of the largest stumbling blocks, aside from rapidly changing research direction and the willingness to support long-term studies, is that both Federal and state agencies now include statements in their Forest Plans and Tree Improvement Plans that prohibit the

introduction and use of non-native planting stock. That can be interpreted in such a way as to exclude another species or a hybrid utilizing a tree several states removed from the planting site, regardless of growth rate or pest resistance. With this type of thinking progress will be slow at best. With enough time and funding, we might be able to produce resistant trees by genetic engineering that can then be mass produced by vegetative propagation. We should change our thinking a bit and use new species or hybrids with wide genetic diversity that will be able to survive the natural changes in the virulence and appetites of the major pests in the Northeast.

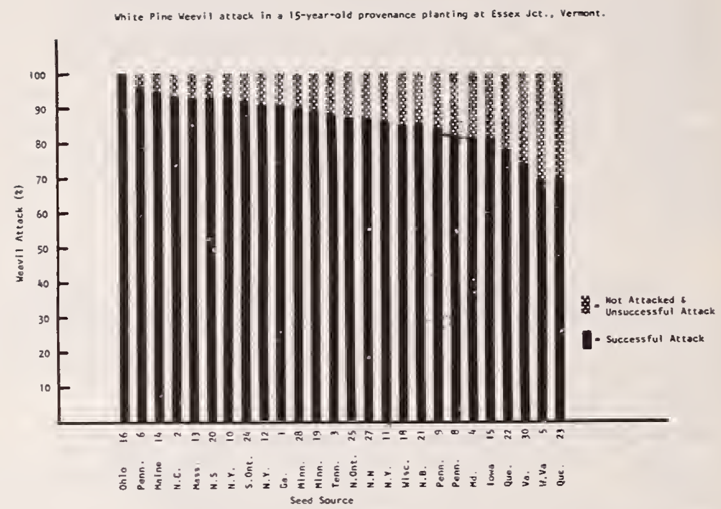

Figure 2.--White pine weevil attack in a 15-year old provenance planting at Essex Jct., Vermont.

Figure 1.--Close crown eastern white pine in southeastern New Hampshire showing repeated weeviling.

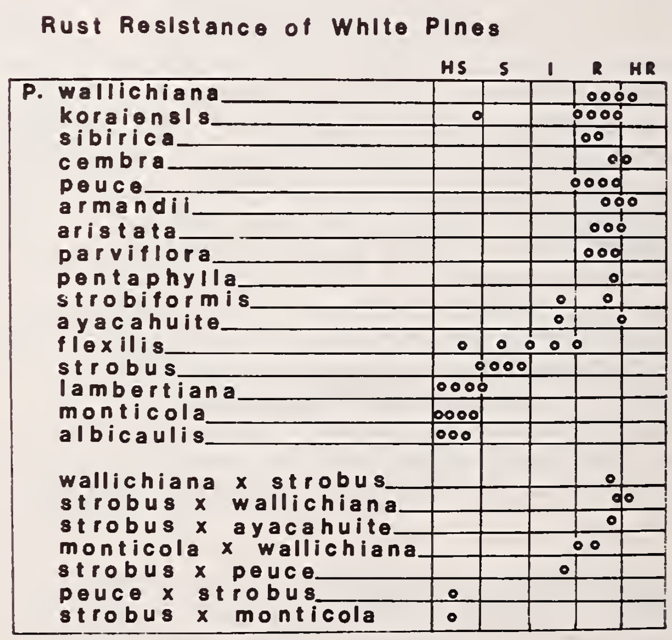

Figure 3.--Rust resistance of species and hybrids of 5-needle white pine. Left to right: Highly susceptible to highly resistant.

[A more comprehensive list of important literature pertaining to these problems is available from the author.]

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ENTOMOLOGICAL PROBLEMS IN GROWING WHITE PINE

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White pine has numerous insect pest problems, but in this review paper we discuss only three: a relatively new pest, the regeneration weevil; an occasional problem pest, the introduced pine sawfly; and an old, yet perennially serious pest, the white pine weevil.

Over eighty separate insect species have been recorded feeding on or damaging white pine, *Pinus strobus* L. These insects have been categorized as leaf feeders, wood borers, root feeders, sucking insects, pollen feeders, terminal borers, bark beetles, cone predators, and nesting insects (Baker 1972). Thus, insects attack almost *every* part of the tree, and *some* insect may attack almost *every* stage in the life cycle of the white pine from seed or seedling to mature tree.

The geographic ranges of these insects coincide with the range of white pine which extends from Minnesota to Maine and from Newfoundland to Georgia; hardly any area or land owner escapes being influenced by the " Entomological Problems in Growing White Pine".

Obviously, we cannot cover all the insect pests of white pine, so we will concentrate our discussion on a few of the most important species, at least in the Northeast and the Lake States: the regeneration weevil, the introduced pine sawfly, and the white pine weevil.

Regeneration Weevil

Although not restricted in its host preference to white pine, a seedling debarking weevil (*Hylobius congener* Dalle Torre, Schenkling and Marshall) has recently become a problem in Maine and the Maritime Provinces of Canada. This new pest problem was identified from a white pine plantation on International Paper Company lands where 44% of the seedlings were killed by the feeding-girdling activities of this debarking weevil.

Research was initated by Celeste Welty, an M.S. entomology graduate student, in 1982-83 to investigate: 1) host susceptibility and 2) how weevil abundance and debarking damage is influenced by planting site characteristics including duff, slash, intra-site location, stumps, site preparation methods, previous stand type, and age or amount of time since harvest (Welty and Houseweart in press).

Because this weevil is similar in its habits to the more familar Pales weevil which is more prevalent in the southern United States, we used split-bolt traps to monitor weevil abundance similar to the procedures used in the South. No major effect of previous stand type was found between the softwood and mixedwood sites. However, a major population decline was evident midway through the second season after cutting, while populations remained high on freshly-cut (1 year old) sites.

We used black spruce [*Picea mariana* (Mill.) B.S.P.] seedlings for debarking damage assessments in all plots (n = 25 seedlings per plot). The planting of black spruce is favored in Maine because of the reduced susceptibility of the species to spruce budworm, *Choristoneura fumiferana* (Clemens), defoliation.

In the duff experiments up to 28% less debarking damage occurred when duff was scraped back in a 30 cm diameter circle from seedling stems than when duff was left intact. Significantly lower percentages of seedlings were debarked at interior plantation locations than near plantation edges. Planting sites which had been prepared by burning in conjunction with either disk-trenching or raking had significantly less debarking (20% less) than controls or simple whole-tree harvesting.

Debarking damage was not significantly influenced by proximity to stumps (hardwood or softwood) or by amount of slash, but trends were evident as would be expected; slightly more seedling damage was detected near stumps and on plots with a greater abundance of fresh slash.

In the species preference tests, all nine species of conifers regularly planted in Maine were attacked by *H. congener*.

Introduced Pine Sawfly

The introduced pine sawfly, *Diprion similis* (Hartig), is a major problem on white pine in the Lake States, especially Wisconsin and Minnesota; it also occurs in the Northeastern States and actually got its start in Connecticut after being imported in the cocoon stage on nursery stock at New Haven in 1914 (Coppel *et al.* 1974). This sawfly seems to be a minor, yet omnipresent, component in the pest complex in Maine and New Hampshire white pine stands, but it was considered a major new pest problem recently (1977-78) in North Carolina. Previous to 1977, *D. similis* was known only to range into southern Pennsylvania, so when it was discovered in the mountains of western North Carolina, the white pine growers (primarily Christmas trees) where taken by surprise and the presence of a new pest problem caused considerable alarm. The State and Private Forestry division of the USFS surveyed the infestation area (Drooz *et*

al. 1979) using Pherocon II pheromone traps and a synthetic pheromone identified by Coppel et al. (1960) and Casida et al. (1963). H. A. Thomas et al. (1982) delineated the infestation area as encompassing 15,500 km^2 of the contiguous portions of Tennessee, North Carolina, and Virginia.

Normally a cadre or guild of natural enemies (e.g. insect parasites and predators, insect pathogens, and small mammal predators) keep populations of the introduced pine sawfly in check. There have been attempts to transfer some of the more effective parasites from the Lake States to North Carolina to reduce the defoliation and provide a biological control of this pest.

Some of the sawfly's more important insect parasites have been identified by Weber (1977) and include the solitary ichneumon wasp, *Exenterus amictorius* (Panzer) and the gregarious torymid, *Monodontomerus dentipes* (Dalman).

White Pine Weevil

The white pine weevil, *Pissodes strobi* (Peck), was first described in 1817, and since that time has been one of the most intensively studied forest insect pests, ranking comparably with the gypsy moth, the spruce budworm, or the southern pine beetle. Yet, the white pine weevil continues to be the major impediment to the culture and management of eastern white pine. The problem is greatly complicated by findings that at least 23 different tree species (both native and exotic) serve as hosts for this weevil (Smith and Sugden 1969).

Serious questions have been posed about the economic feasibility of white pine lumber production in the Northeast via planting due to: 1) the persistance of weevil attack and 2) the lack of effective control measures. Although the weevil infestation rarely causes tree mortality, volume loss, lumber degrade, and loss in rotation time can be severe. Waters et al. (1955) and Ferguson and Kingsley (1972) reported losses of 40% bd.ft. volume of saw timber trees and board quality reductions of 1 to 3 grades. The results of yearly growth reductions in Maine are shown in Figure 1 by Dixon and Houseweart (1983) .

Our research efforts in Maine have concentrated on studies of life tables, spring and fall behavior, fall insecticide trials, and fall shading experiments.

From the life table studies, (a life table is simply a record of mortality and the causes of that mortality) Dixon and Houseweart (1982) identified that white pine weevil mortality was greatest in the larval, pupal, and the winter adult stages. Therefore, the conclusion was that population suppression methods should be directed

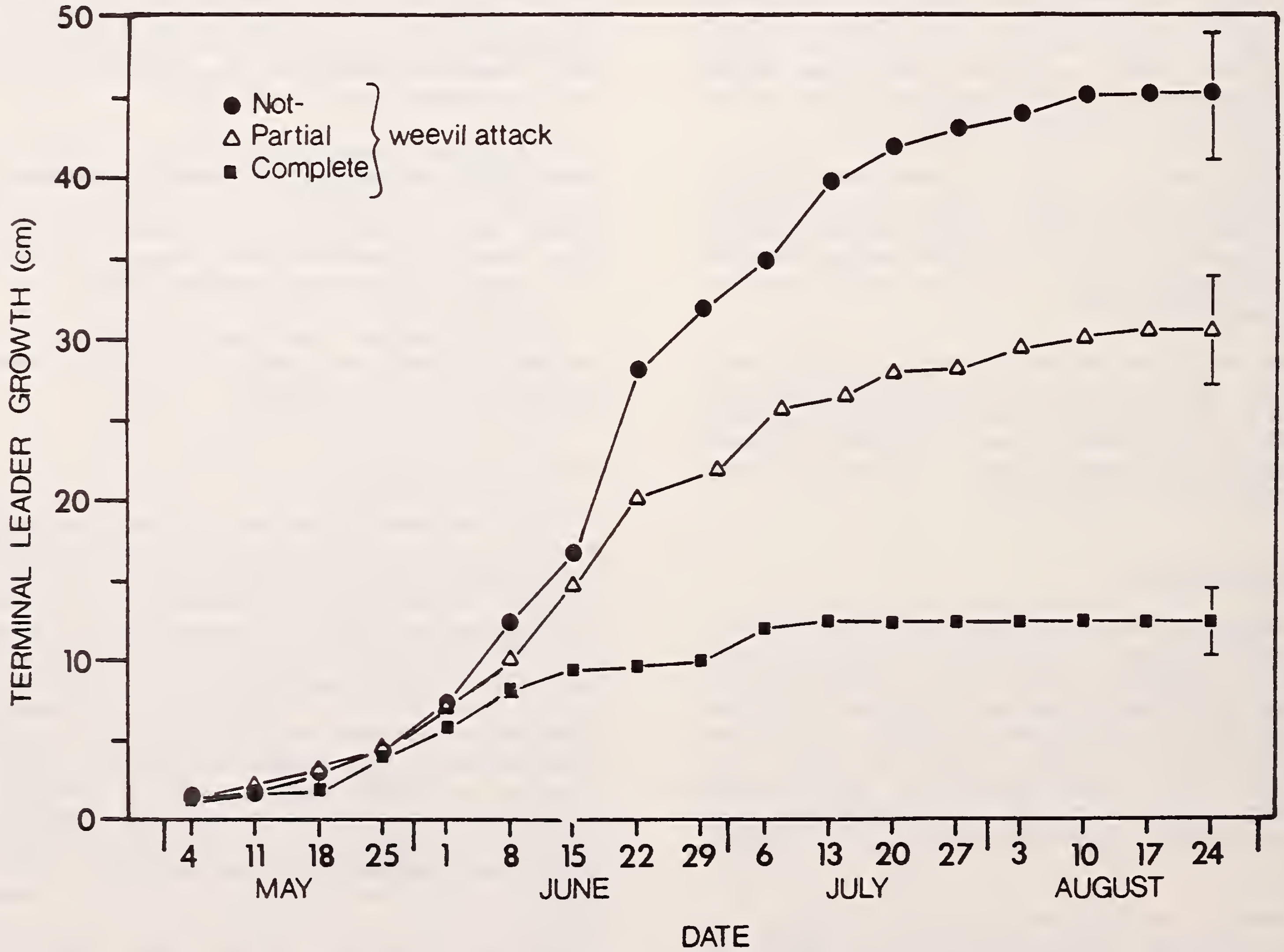

Figure 1. Terminal leader growth of three types of weevil attacked trees.

at these stages to be most effective against weevil populations. The separation of mortality between fall brood adults and those overwintering has not been investigated to determine which sub-stage may be more important in total mortality.

During the course of fall weevil behavior studies, Dixon et al. (1979b) discovered several factors concerning fall and winter weevil populations which led to additional studies of suppression methods:

1) weevils remain on brood tree foliage from mid-August to mid-October with a peak abundance near mid-September;

2) most of the weevils are found feeding on current-year buds and stems, and must feed in order to survive the winter;

3) over 85% of the brood adults are located in the top one-third of the tree, predominately on lateral (more horizontal) branches, while the spring adults are primarily confined to terminal (vertical) branches;

4) adults leave the trees to find over-wintering sites in the litter by mid-October;

5) most weevils overwinter within 20 cm of the boles of host trees.

A comparison of the data with that on spring weevils (Dixon and Houseweart 1983) pointed to the fall and overwintering winter stages as times when weevils may be especially susceptible to control techniques. Fall insecticidal spraying has the following advantages over spring applications: 1) weevils are accessible for a longer period of time, 2) timing is not as critical, 3) adults are exposed on more horizontal targets (laterals) than in the spring (vertical terminal leaders), 4) beneficial insects are inside damaged leaders and are not exposed to insecticides as they are in the spring, and 5) weather is generally better for spraying in the fall.

Several experimental trials have been conducted: in 1978, using three chemicals (Pounce, Carbaryl, and Methoxyclor) applied via helicopter (Dixon et al. 1979a); in 1984, using six chemicals (Pounce, Pydrin, Methoxyclor, Sumithion, Rabon, and Dursban) applied from the ground and compared with a hand-pruning control and a no-treatment control (McGalliard and Houseweart 1985); in 1979 and 1980, using a controlled burn and litter rake treatments to destroy overwintering adults (Houseweart 1981).

The shading of young white pine by a hardwood or conifer overstory has long been recognized as a viable silvicultural control method for the weevil. Hardwood canopies, however, may only be inhibitory in the fall because spring weevil activity is well underway before the hardwood leaves have developed. Sullivan (1961) states that a shaded environment influences weevil feeding and oviposition behavior because of the smaller leaders produced by the trees growing in the shade. Weevils are responsive in the spring to bark temperature, diameter of the host leader, and light. These and other physical factors have recently been reviewed by Wallace and Sullivan (in press).

Experiments on the behavior of weevils in the fall provide some variations on these conclusions (Droska 1982). It was shown that weevils are strongly stimulated by ultra-violet light sources (Droska et al. 1983); field experiments suggest that weevils emerging from trees in shaded environments in late summer leave those locations seeking areas with more sunlight. A hardwood canopy absorbs most of the ultra-violet light in the spectrum, thus very little reaches the understory. A full understanding of fall behavior is elusive; it cannot be assumed that light is the only influence or even the major factor. Tree vigor seems to have a strong effect even though fall feeding is not confined to the terminal leader. In open locations weevils are found in greater numbers on the large vigorous trees than on the more suppressed individuals in a stand.

There may be a strong chemical attraction of some type that has an effect on weevil behavior in both spring and fall. The very strong orientation to feeding and ovipostion on the terminal leader cannot be totally explained by the factors of light, leader diameter, bark temperature, and vertical position.

Booth and Lanier (1974), Phillips (1981), and Booth et al. (1983) have studied and reported on weevil aggregation pheromones. Their results indicate: 1) the presence of a pheromone complex (grandisol and grandisal), and 2) that there seems to be a synergistic effect to the attraction when the host odors are combined with the weevil pheromone.

In conclusion, the white pine resource in the Northeast is here and here to stay - today and tomorrow. What we as managers of this resource must do is to manage it wisely. Through the use of all of today's and tomorrow's suppression methods, whether they be chemical, biological, or cultural, we must also learn to manage our entomological problems.

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DISEASES OF EASTERN WHITE PINE

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Abstract

Eastern white pine is subject to several biotic and abiotic diseases, but none seriously threaten its culture at the present time. Blister rust (Cronartium ribicola) can be a serious problem throughout the range of this species, but judicious management practices can reduce losses to an acceptable level. White pine root decline (Verticicladiella procera) is a relatively new problem affecting white pine, but neither the factors affecting disease severity nor means of control has yet been worked out. A similar disease called basal canker, which is associated with ants, several canker fungi, and winter injury, can be locally damaging in natural stands and plantations. Root rot caused by Heterobasidion annosum may sometimes cause losses in thinned white pine stands. Eastern white pine is very sensitive to several air pollutants, especially ozone, sulfur dioxide, fluoride, and nitrogen oxides. These agents produce several types of symptoms known variously as chlorotic dwarf, emergence tipburn, and semimature tissue needle blight.

Eastern white pine is subject to a large number of biotic and abiotic diseases which affect all parts of the tree and which may result in death, growth reduction, or product degrade. However, no one disease poses a serious threat to continued culture of this important tree species. This paper describes a few of the more important diseases of eastern white pine and discusses means for their prevention or control.

White Pine Blister Rust

Since its introduction into the United States about 1900, white pine blister rust (Cronartium ribicola) has caused severe losses in stands of both eastern and western white pine, although impact on eastern white pine has been somewhat less. The fungus infects pine through the needles and then spreads into the branch or stem, which eventually dies after being girdled. The needles on branches killed by the rust turn reddish copper but remain attached throughout the summer that they are killed. These "flags" in the crown of an infected tree are useful indicators of the presence of the disease, as are the characteristic spore pustules that later appear on the bark. These blister-like structures give to the disease its common name, "blister rust."

White pine blister rust is a long cycle, heteroecious rust. That is, it produces five types of spores and requires an alternate host--species of Ribes, commonly known as currants or gooseberries--to complete its life cycle (Nicholls and Anderson 1984). The absolute necessity for an alternate host and the exacting environmental requirements for the formation and spread of the various spore stages are the basis on which various disease management recommendations are made.

Pycnia, the sexual stage of the fungus, first form in the bark on cankers during August of the third season after infection. The following spring, aeciospores are produced in the same area where the pycnia were formed earlier. These spores are thick-walled, resistant to adverse environmental conditions, and capable of spreading for hundreds of miles from pines to reach susceptible Ribes plants. Since these spores cannot reinfect pine, the life cycle would be broken in the absence of Ribes. This is the basis for the Ribes eradication program carried on for many years in the white pine regions of both the Eastern and Western United States. The program, as well as prohibiting the planting of cultivated species of Ribes, is still in effect in a few places (e.g., Maine).

About 2 weeks after successful infection of Ribes leaves by aeciospores, another spore stage called urediniospores are produced in small, orange pustules. The urediniospores can infect only Ribes and are responsible for intensifying rust infection on the same or other Ribes plants throughout the summer.

In late summer or early fall, the telial stage of the fungus appears as short, brownish, hair-like structures on the underside of the Ribes leaf. These structures are composed of many closely packed teliospores that germinate in place to produce yet another spore stage called sporidia, which can infect only pine. These spores have thin walls, and are very sensitive to adverse environmental conditions. For this reason, spread of the fungus from Ribes to pine is limited to a few hundred feet. Production of sporidia and subsequent spread to and infection of pine requires a continuous period of at least 48 hours of temperatures below 20°C and free moisture on the needle surface.

These stringent requirements for spore production and pine infection have led to the delineation of rust hazard zones based on the probability of these conditions occurring. Hazard zone maps have been prepared for the

Northeast (Charlton 1963) and for the Lake States (Van Arsdel 1964) and are used to make decisions on whether to include white pine in management plans or to apply various control measures (Robbins 1984).

On sites with low risk of infection, white pine can be safely grown without control measures being applied. On sites with moderate risk, pruning may be all that is necessary to prevent serious losses from the disease. This practice is not only valid from a silvicultural standpoint, it also prevents spread of branch cankers into the stem providing they are more than 4 inches from the trunk at time of pruning (Lehrer 1982; Nicholls and Anderson 1977). Pruning should begin 3 years after planting and continue periodically until at least the first 9 feet of the bole is free of branches. On high-hazard sites, planting other tree species or rust-resistant white pines, along with pruning, is recommended. _Ribes_ eradication around high-value crops, such as Christmas tree plantations and nurseries, also may be economically feasible. On landscape and specimen trees, removal of branches with cankers is an effective means of control.

White Pine Root Decline

White pine root decline, a relatively new problem on eastern white pine, is known to occur in Ohio, Iowa, and Indiana in the Midwest; and New York, Virginia, West Virginia, Pennsylvania, Maryland, North Carolina, and South Carolina in the East (Anderson and Alexander 1979, Lackner and Alexander 1984). The causal organism, _Verticicladiella procera_, has been isolated from several other _Pinus_ spp. as well as Norway spruce and grand fir. However, white pine appears to be the principal host, and the disease currently is most damaging to white pine Christmas trees and landscape plantings in New York, West Virginia, Pennsylvania, and Virginia. Losses in some Christmas tree plantations have reached 20 percent or more (Anderson and Alexander 1979). The disease apparently occurs less commonly in natural stands.

Characteristic symptoms of white pine root decline include a rapid wilting and yellowing of the entire crown of infected trees. In Virginia, the first symptoms are noted in late February or early March, and trees are dead by mid-April. Trees that do not exhibit normal bud break usually develop similar symptoms and die by middle to late May. Other trees die at various times during the summer and early fall (Lackner and Alexander 1982).

Resin exudation usually occurs at the base of infected trees. When the outer bark is removed, a sharp line of demarcation can be seen between healthy tissue and the resin-soaked, dark brown to black, discolored affected tissue, which extends upward for 40 to 50 cm above the root collar and downward into the roots.

Little is known about the infection process and subsequent disease development. Infection apparently takes place in the root collar area. Several insects, including bark beetles and weevils, have been observed associated with infected tissue; but there is no evidence that they are involved in the infection process (Lackner and Alexander 1984). However, insects have been implicated as vectors of a similar disease of western conifers caused by _Ceratocystis_ (_Verticicladiella_) _wagenerii_ (Goheen and Cobb 1978). The pathogen has been isolated from soil around roots of infected trees, but once the root system of diseased trees is removed, populations of the pathogen rapidly decrease (Lackner and Alexander 1984). However, if seedlings are planted in infested soil, they become infected and die.

The disease appears to occur more commonly on heavy, poorly drained soils. Little else is known about effects of site and environmental factors on disease development.

Much more information is needed about the disease before effective control procedures can be devised. In the meantime the following recommendations have been made to reduce loss in white pine Christmas tree plantations (Anderson and Alexander 1979).

1. Avoid planting on heavy, poorly drained soils.

2. Remove infected trees, including roots.

3. Do not replant infested areas.

Basal Canker of White Pine

A similar disease called basal canker of white pine was first described from young plantations on the Tug Hill Plateau in North Central New York by Houston (1969). Later the disease was also observed in young plantings established as living fences along Interstate Route 95 in central Maine (Houston 1975). The disease has continued to intensify slowly in these areas since the early 1960's. The Tug Hill plantations are being harvested prematurely because of the disease, and white pine will not be replanted. The disease has also been reported in New Hampshire.

Crown symptoms on trees with basal canker are similar to those with white pine root disease, although progress of basal canker is somewhat slower (Houston 1969). Affected trees may change from a healthy green to yellow to reddish brown in a year or less. Cankers occur on the main stem from ground level up to about 60 cm. They are first evident as irregular sunken, reddish areas usually associated with lenticels or injuries. Several such areas may coalesce to form larger, depressed cankers

which may girdle the stem. Bark over the canker usually persists after it has been killed, and recently killed bark and underlying sapwood often are eaten by rodents, which causes many trees to break over at the canker.

The etiology of basal canker of white pine is very complex. Several fungi have been isolated from cankers, but only *Pragmopara pithya* has the ability to cause perennial cankers. The fungus cannot successfully invade except via a wound. The infection court commonly is furnished by small lesions produced by chewing wounds, usually around lenticels, made by ants (principally the black meadow ant, *Formica fusca*). These lesions are caused when the ant discharges formic acid into the wound during chewing. Severity of basal canker in an area is directly related to the number of ant colonies and the distance of the tree from ant mounds.

The fungus can also invade through wounds caused by ice and snow damage, although for reasons unknown, only basal wounds usually become infected. Cankers associated with wounds are more numerous in plantings oriented perpendicular to the prevailing winds where snow damage is greatest (Houston 1975).

Losses from the disease can be decreased by direct control of ants where they occur in large numbers, and by not planting white pine on the lee sides of hedgerows, snow fences, and rock piles, and in depressions where heavy snow and ice persist.

Annosus Root Rot and Butt Rot

Heterobasidion annosum (syn. *Fomes annosus*) attacks numerous conifers throughout the temperate areas of the world. In the United States, it is a serious problem primarily in the South and West but occasionally may cause substantial damage in plantations and natural stands of eastern white pine throughout its range.

Initial stand infection usually occurs on the surface of freshly cut stumps by airborne spores of the fungus. The fungus then colonizes the stump and its root system and spreads to the adjacent healthy trees by root contact. Further tree-to-tree spread by root contact results in a more or less circular infection center, with dead trees in the center surrounded by living trees showing various degrees of crown symptoms. These symptoms include chlorosis, reduced leader and twig growth, and premature needle drop resulting in a thin crown. *Heterobasidion annosum* should be strongly suspected as the cause of tree death when mortality in a stand begins in the second or third year after thinning and continues for several years.

The fungus decays the root system, and windthrow is common. Many trees will be windthrown prior to exhibiting visible crown symptoms. Unlike most other pines, white pine is susceptible to butt rot as well as root rot.

Fruiting bodies of the fungus often can be found at the base of infected trees or stumps. These are typically bracket-like, up to 15 cm long and 10 cm wide, with a dark brown upper surface and creamy white lower surface. However, they are often much smaller and are frequently covered by litter. Fruiting bodies do not form on all infected trees.

More detailed descriptions and excellent illustrations of the fungus and disease can be found in papers by Robbins (1984) and Froelich and others (1977).

The cut surface of the stump of recently felled trees is the critical part of the life cycle of annosus root rot, and the disease can be controlled by preventing stump infection. This is best accomplished by applying powdered borax to the stump surface immediately after felling (Froelich and others 1977). However, this material should not be used in stands where the disease is already present. A spore suspension of *Phlebia* (*Peniophora*) *gigantea*, if available, should be applied instead.

In the South, prescribed burning plantations of loblolly and slash pines before thinning has reduced the amount of disease that developed following thinning (Froelich and others (1977). However, no information on the effect of burning is available for white pine stands.

Air Pollution

Scientists have been aware of the phytotoxic effects of gaseous air pollutants produced as the result of certain industrial activities for more than a century, but experimental evidence of the compounds involved and their specific effect on individual plant species have come only in the past 2 or 3 decades. Conifers, because of their long life and needle retention for 2 to 3 years, are among the most sensitive of plants to air pollution. Eastern white pine is generally considered one of the most sensitive conifers.

There is voluminous literature on the effects of measured concentrations of specific toxic compounds on individual plant species, including eastern white pine (see Gerhold 1977 and Skelly and Johnson 1979). Acute symptomatology and effects on the whole plant and at the tissue and cellular levels are well documented. Less well documented are effects of long-term, low-level pollutant episodes and ambient mixtures of various air pollutants on individual tree species. Even less is known of the effects of air pollution on forest ecosystems as a whole.

The effects of air pollutants on eastern white pine vary widely, depending on the compound or mixtures of compounds involved, dosage, length of exposure period, certain environmental factors, such as humidity and temperature, and the relative sensitivity of individual trees. Foliar symptoms may include chlorosis, needle mottle, necrosis of needle tips, and premature needle drop (Gerhold 1977). Some physiological effects of air pollution injury include decreased rates of photosynthesis, and increased respiration rates, levels of carbohydrates, and reducing sugars. Prolonged exposure often results in a decrease in height and diameter growth (Benoit and others 1982), sometimes even in the absence of visible foliage symptoms (Chevone and others 1983). Numbers of seeds per cone, seed weight and percent germination, and percent pollen germination may be reduced (Houston and Dochinger 1977). Trees weakened by air-pollution injury often are more susceptible to attack by pathogenic microorganisms and insects (Lackner and Alexander 1983).

Several specific compounds have been associated with injury to eastern white pine. The most important of these are ozone, sulfur dioxide, nitrogen oxides, and fluoride.

Ozone is a naturally occurring component of the atmosphere, where it is found at normal concentrations of 3 to 5 parts per hundred million (pphm). These levels may be augmented by the generation of ozone and ozone precursors from numerous urban and industrial sources, which are then widely distributed into remote forested areas with the movement of high-pressure weather systems (Wolff and others 1977). Ozone concentrations of 7 to 20 pphm or sometimes higher have been recorded in forested areas in the Midwest, Northeast, and Appalachian areas (Duchelle and others 1983, Usher and Williams 1982). These concentrations are known to be phytotoxic to eastern white pine.

The threshold level at which eastern white pine is visibly injured by ozone varies widely depending on the sensitivity of individual trees or clones tested. Acute injury may occur on elongating needles after exposure to as little as 6.5 pphm for 4 hours (Berry and Ripperton 1963). Higher concentrations are needed to injure more tolerant individuals. For example, among clones selected for sensitivity to tipburn, none were injured when fumigated with 5 pphm for 6 hours; 20 percent were injured at 10 pphm; 60 percent at 30 pphm; and, 20 percent at 60 pphm (Houston 1974).

Heritability studies indicate that tolerance to high levels of ozone is under strong genetic control (Houston and Stairs 1973), and considerable progress has been made in developing resistant lines. The differential susceptibility of individuals of eastern white pine to different concentrations and kinds of air pollutants has resulted in their use as biological indicators (Berry 1964).

Unlike ozone, concentrations of sulfur dioxide high enough to cause significant injury to plants are usually found only in the vicinity of industrial complexes such as smelters, petroleum refineries, and coal-burning power-generating stations. There is usually a concentration gradient of SO_2 that decreases with distance from the point source, with the maximum distance at which injury occurs depending on concentration at the source, the relative susceptibility and age of the plant species, temperature and relative humidity. Eastern white pine is considered among tree species most sensitive to sulfur dioxide. Some trees may be injured at concentrations as low as 5 pphm for 4 hours; but, as with ozone, considerable variation in tolerance to sulfur dioxide occurs among individual white pine clones (Yang and others 1983).

A disease known as chlorotic dwarf is common throughout the Eastern and Midwestern United States (Dochinger and Seliskar 1970). Characteristic symptoms include yellowed or mottled needles that are shorter than normal, premature needle fall, and shortened internodes. The cause of the disease is believed to be chronic exposure to low levels of a combination of ozone and sulfur dioxide. There is wide variation among individual white pine in susceptibility to chlorotic dwarf, which can be exploited by discarding sensitive seedlings during nursery grading operations based on needle mottling as the selection criteria.

The logical solution to the air pollution problem is, of course, reducing the pollutants to levels below those which plants, including eastern white pine, are injured. Considerable progress has been made in doing this, especially with sulfur dioxide and fluoride, which are generated from easily identifiable point sources. Ozone levels, however, have continued to increase, and will undoubtedly remain a serious problem in the foreseeable future. Progress also has been made in the identification and selection of white pines with resistance to different air pollutants, but much remains to be done before they are propagated and widely distributed.

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IF THE PRICE IS RIGHT: OHIO WHITE PINE TO SUPPLY MEAD PAPERS LONG-FIBER PULP REQUIREMENTS

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Mead Paper's has committed $64,000,000 to renovate and upgrade the pulp mill and woodyard tô produce not only hardwood pulp, but also 705 average tons per day of pine pulp. Pine pulpwood requirements will go from zero to 250,000 tons per year beginning in December, 1985. White pine will be the major species in Mead's establishment of 35,000 acres of controlled pine plantations.

If the price is right. The title of this short monologue sounds like the beginning of a financial and economical analysis talk on the development of the Ohio white pine market. Be advised that such an analysis will always be left to more learned colleagues. The title does represent, or more characteristically, embodies, a later attitude that created a portion of the coniferous acreage and volume in Ohio. Except for Christmas tree plantations, and even here the residual stand created a forest plantation, the conifer plantation area of Ohio was established for either one of two reasons:

1. The fact that conifer species were more available, survived, and grew better than planted native hardwood species.

2. The conservation movement in the first half of this century.

One must realize that Ohio had very little pine in pre-settlement days and little, if any, by the turn of this century. In the 1942 forest survey, only 12 percent of total land area was forested. (Diller, 1944)

From the standpoint of survival in old field plantations, it was soon evident that the conifers not only outgrew the hardwoods BUT just as importantly, the conifers were very competitive with the growth from native hardwood forests. We now know that there are reasons for the hardwood species lack of response in old field plantation establishments. But that fact aside, and even if growth was not a consideration, two additional attitudes concerning "pine" plantation establishment held forth. One attitude held that by establishing the plantation, the site would be improved for the eventual natural conversion into a hardwood forest. Today, there are pine plantation owners who have as an integral part of their management plan, the allowance of harvested pine plantations to naturally revert to hardwood forests. The other attitude that prevailed, not necessarily separate nor distinct from the above attitude, reflects the title of this paper. This attitude noted that if enough "pine" plantations were established and sufficient volume was grown, that a market would be born. In other words, a supply would create a demand and the price would be right.

In the Hill Country of Ohio, especially, the conservation movement included the planting of trees, primarily conifers, on the worn out, abandoned, gullied, farm lands. By 1942, approximately 90,000 acres of forests were planted by national, state, and private agencies (Diller, 1944). Public agencies planted 42,565 acres of this total. A typical private planting was less than five acres in size and was composed of red, white and Scotch pines or a mixture of these species (Diller, 1944). By 1952, softwood types totalled 116,000 acres (Hutchison, 1954); by 1967 softwood types totalled 279,500 acres, up 141 percent since 1952 (Kingsley, 1970); and by 1979, they had reached 305,800 acres (Dennis, 1981). The 1979 inventory gave net volume of pine growing stock at 274.9 million cubic feet for all pine species.

It should be noted, before a wrong impression is made, that not all the softwood type acreage nor all the volume is represented by plantations. Mother Nature did her thing in reforesting the worn out land and "Virginia pine is primarily of natural origin in Ohio" (Dennis, 1983). Today a forest survey would show acreages and volumes for red pine (Pinus resinosa Ait.), white pine (Pinus strobus L.), shortleaf pine (Pinus echinata Mill.), Virginia pine (Pinus virginia mill.), Eastern red cedar (Juniperlus virginia L.), and Oak/Pine types.

This wide variety of conifer species has documented an added bonus. Ohio forestry, voluntarily or involuntarily, has been involved in a seventy year old conifer selection research project. And the winner is - Eastern White Pine. There is almost universal agreement that Eastern white pine is the best conifer species to plant for maximum growth either for pulpwood or sawlog products, short or long rotations, in Ohio. Mead Paper endorses this selection.

Eastern white pine, a major component of Ohio's pine forest type, has an excellent plantation survival and growth history. It has demonstrated an ability to produce well on a wide variety of sites and the impact of insect and disease pests are either nonexistent or of minimum detriment. Mead's examination of its growth showed growth rates of 1.5 to 2.5 cords per acre per year and occasionally, even higher growth rates were tabulated. A Mead procurement forester[1/] surveyed a 32 year old, four acre, red and white pine plantation. From the white

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1/ Personal correspondence with Mr. Jeffrey Hoselton, Procurement Forester, Mead Paper, Woodlands Department, Chillicothe, Ohio.

pine volume alone, he calculated an average volume per acre of 192 tons. The 53 year old white pine stands at Waterloo State Forest[2/] showed, in a 1970 survey, net volume after several thinnings of 44,000 board feet (Int. 1/4 rule). Site index (35 year) calculations (using Brown & Stires, 1981, equations) of 42 trees from eight plantations, six age classes (17-57 years), and four slope positions, gave a value of 87. One 20 year old plantation showed a site index value of 94. And most of the seedling stock was from Ohio or northern seed sources. If genetics and tree improvement factors for white pine can be introduced, the results should be even better. Ohio Agricultural Research and Development Center has thirty years of research on white pine selections for growth and yield in Ohio (Kriebel, 1982, and Kriebel, 1983). And there are several other sources of information if Mead desires to establish a seed orchard. The Ohio Division of Forestry is establishing a three acre seed orchard, using these sources. Otherwise, excellent seed sources are known and documented. It is Mead's goal to utilize the best seed sources possible in growing the future planting stock.

The Mead Paper, Fine Paper Division mill has existed at Chillicothe for 150 years. In 1984, the mill produced 625 TPD (tons per day) of hardwood pulp using the Mead Hardwood Kraft process; utilized 824,000 tons of hardwood pulpwood; and produced a paper product mix that included form bond, coated paper, safety paper and carbonless business form paper.

Beginning in July, 1984, construction began on a $64 million pulp mill - woodyard renovation and upgrade. The purpose of the project is to rebuild the woodyard and pulp mill to produce hardwood pulp at 830 TPD (up from 625 TPD) and softwood pulp at 705 TPD (up from zero TPD). The pulpwood consumption will increase from 824,000 TPY (tons per year) to 1,200,000 TPY by 1986. A fifty percent increase. The pulpwood mix will revert to primarily longwood with 26 inch maximum diameter and twelve foot minimum length. This will decrease the whole-tree chip consumption from 65 percent of total tonnage to 25 percent. Hardwood pulpwood demands will total 700,000 TPY; whole-tree chip and sawmill chips will total 250,000 TPY; and pine pulpwood demands will total 250,000 TPY.

It should be noted here and now, that Mead Paper has always utilized pine pulp (or more exactly long-fiber) in its paper making process. The renovation and upgrade of the pulp mill now allows Mead to pulp "pine" pulpwood from local sources. The mill will utilize all species of pines with longwood standards similar to the hardwood pulpwood. This utilization is scheduled to take place beginning December, 1985. The pulp mill is scheduled to pulp hardwoods for seven days and softwood for one day per eight day period.

The procurement of standing pine timber has begun and Mead is actively involved in the Ohio pine marketplace. Beyond Mead's normal sixty mile radius, hardwood procurement area, additional pine procurement foresters have been assigned to set up concentration yards in Ohio, West Virginia and Kentucky. The pine procurement radius is set at approximately 160 mile limit. To say that Mead's entry into the pine market of Ohio has caused a splash might be considered an understatement. Whereas past public or private sales might solicit one or maybe two price quotations, such sales are now obtaining five to ten bids and stumpage prices are rattling all up and down the scale, mostly up. Just how the price settles out will give everyone a short course in marketplace economics.

Although Mead's immediate pine volume requirements are very important to the mill's continued health, so also are its future requirements. The pine reforestation program has as its purpose, the establishment of 35,000 acres of controlled stumpage area by 1995. This represents 65 percent of projected tonnage needs. As noted earlier, the principle conifer specie will be Eastern white pine. The program will utilize both company owned and company leased land and will reforest old fields or will convert selected upland hardwood sites to pine plantations. The rotation will be 25-35 years. By 1987, the plan calls for the planting of 3,500 - 4,000 acres annually. Plans are to use both machine planters in the old field areas and hand planters in the hardwood conversion areas. Both bareroot stock from the Ohio Division of Forestry - Marietta State Nursery and containerized seedlings from Mead's Escanaba greenhouse nursery will be planted. Presently, a 20,000 square foot shadehouse with irrigation and fertilization systems is being readied for the arrival of 900,000 containerized white pine seedlings. By 1987, the shadehouse area will be doubled. A cold storage unit has been erected for the sub-freezing, over-winter storage (seedlings lifted in November) of 1.5 million white pine seedlings. The Marietta State Nursery has had, with Mead's assistance, its irrigation system upgraded. Whenever possible, the white pine seedlings will be raised from genetically superior seed either from wild trees of selected counties in Tennessee or seed orchard seed - North Carolina or Ohio.

A significant section of the reforestation program is the upland hardwood, site conversion operation. For this, the whole-tree chip, clearcut operation will become the fundamental site preparation tool. Within 12-18 months of cutting, the site will receive additional chemical and mechanical site preparation. The chemical site preparation will involve the application of herbicides to control the hardwood and herbaceous brush competition. Trials are presently underway to test the sensitivity of white pine to the various herbicides. Mechanical site preparation may include roller chopping and patch scarification.

[2/] Personal correspondence with Mr. John Dorka, Staff Forester, State Forest Resource Management Section, Ohio Division of Forestry, Columbus, Ohio.

Burning, such as that being utilized in the South, is not presently planned. The hand planting of containerized seedlings will take place the following spring growing season. Approximately 80 acres were planted with bareroot stock in 1985 and an inspection of the planting this week indicated decent survival and growth, given they experienced the driest April in 46 years. Plans are to convert 850 acres in 1986 and 1,500 acres in 1987. Environmentally, Mead is well aware of the impact, potential or otherwise, of such activities. Every effort is being made to make the neighboring landowners knowledgeable of the activities and Mead will intensively monitor and evaluate the environmental impact of these initial efforts. As time and experience dictate, refinements to the program will be made, both to improve the environmental impact and the technical efficiency of the hardwood conversion program. If successful, the hardwood conversion program will be installed into the private land, leasing program. Many landowners have expressed interest.

The land-leasing program for growing pine on private, non-company lands is simply a land lease that allows Mead to establish and manage a plantation for thirty years plus or minus five years. At the end of the rotation, a fair market stumpage value price will be paid to the landowner. From the individual landowners, this program has met with reluctance due primarily to the time period involved. But several corporate landowners have expressed an interest, and in 1985, 170 acres of white pine plantations were established on leased land.

Another program that has taken off and was begun by Mead Paper in 1985 is the Cooperative Seedling Program. In cooperation with the Ohio Division of Forestry and administered through their service forestry section, an Ohio landowner may qualify to receive white pine seedlings from the state nursery at no charge. Mead will stand the expense. In 1985, 497,500 white pine seedlings were distributed and for 1986, the program has been increased to 750,000 seedlings. Mead feels strongly about this program. This is a way to get many of the old fields planted and the landowner has no obligation to Mead. Consequently, discussions are now in progress to extend similar Cooperative Seedling Programs into selected counties of West Virginia and Kentucky. It is not now known whether white pine will be the selected species in these state programs.

In conclusion, Mead, Chillicothe is embarking on a wood utilization and reforestation program never before experienced in its 150 year history.

The pulping of pine from local sources is in itself, a new industry.

Add reforestation at 3 million seedlings annually for ten years, plus the Cooperative Seedling Program of 1.0 - 1.5 million seedlings annually, and a mini-reforestation program is born.

From the menagerie of species planted in Ohio's tree planting history, Eastern white pine reigns supreme. Mead plans to exploit these advantages to an extreme.

Certainly with Mead's entry into the pine marketplace, the pine forest management circle has become more complete. So much so, that second rotation plantations are now being considered on both public and private lands.

In the end, maybe all of these marketplace actions will provide:

1. An alternate and viable land use option to forest landowners and managers; and

2. Will allow Mead Chillicothe - Fine Paper Division to maintain its competitive position in the pulp and paper industry. Believe. Therein lies the future. The status of the bottom line.

Always if the price is right.

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WHITE PINE MARKETING OPPORTUNITIES

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The stumpage price of medium quality eastern white pine increased by an annual average rate of 3.1 percent in New Hampshire over the past 11 years. Annual exports of both eastern white and red pine averaged 46.5 million board feet the past 6 years, with more than 22 million board feet of eastern white pine logs going to Canada. The U. S. imports approximately 244 million board feet annually of both eastern white and red pine. The domestic market will continue to be relatively strong and dominate the export.

Introduction

Because of its many outstanding characteristics, eastern white pine has been put to more uses than any other softwood species. In fact, it probably has been put to a greater variety of uses than that of any other wood, except oak. From the days when the trees were blazed with the king's mark and reserved for masts for His Majesty's fleet until today, eastern white pine has been valued for its character, versatility, and durability.

Uses

Building construction was formerly the primary use of eastern white pine. Many 200-year-old homes constructed of almost entirely eastern white pine are still in excellent condition. But after 1900, eastern white pine was superseded by southern pine and Douglas-fir in structural applications. Even so, construction still accounts for 50 percent of the current use of eastern white pine lumber. These uses include millwork, primarily sash and door, trim, molding, finish, sheathing, paneling, wainscoting, clapboards, and shingles. Other preferred applications include pattern stock, woodenware, toys, novelties, furniture, signs, decorative uses, boxes, crates, and caskets.

Production

The production of eastern white pine lumber started in New York about 1630, and soon spread to New England and Pennsylvania (Betts 1945). White pine was undoubtedly the primary species sawn at the Humphrey Chadbourne water-powered "up and down" mill in 1634 at South Berwick, Maine. For 200 years, the pine forests of the eastern States continued to produce increasing quantities of lumber. By 1840, most of the old-growth in the Northeast was cut out and lumbering began in the magnificient pineries of the Lake States.

In 1931, Maine once again took the lead in eastern white pine production, with New Hampshire second. During 1933-1942, New Hampshire ranked first in the production of eastern white pine in 6 of the 10 years, and Maine in 4. In 1942, the three leading States were New Hampshire, Maine, and Minnesota. Those were the early years. Since then, eastern white pine has been the bread and butter species of the Northeast and a stabilizing influence in recent years of economic turmoil. Bob Robinson, president of the Northeastern Lumber Manufacturers Association (NeLMA), reported at the beginning of this year that, "Eastern white pine boards are currently enjoying a better market share including wider distribution and price stabilization."

Price Trends

Prices and annual rates of change in price are helpful in indicating profitability and an expectation of the future.

Average stumpage, roadside, and delivered prices for medium quality eastern white pine in New Hampshire are listed in Table 1 for the years 1975-1984.

Table 1.--Average Annual New Hampshire Statewide Prices of Medium Quality Eastern White Pine Standing Timber and Sawlogs ($/MBF)

	Stumpage	Roadside	Delivered
1975	29	55	68
1976	33	58	69
1977	36	64	80
1978	43	74	92
1979	54	88	113
1980	58	92	116
1981	60	94	118
1982	62	98	123
1983	62	97	123
1984	65	102	129

Source: New Hampshire Forest Market Reports, Cooperative Extension Service, University of New Hampshire, with the New Hampshire Department of Resources and Economic Development cooperating.

The data start after the 1973 oil embargo and do not reflect the sharp increase in price in 1974. There was a decrease in 1975 and, as the data indicate, an overall increase from 1975 to 1984. Changes in real stumpage price, adjusted for inflation, for medium quality eastern white pine in New Hampshire increased at an average annual rate of 3.1 percent over the past 11 years (Remington and Dennis 1985).

Considering all reported New Hampshire species, changes in real stumpage price ranged from -2.5 percent for spruce/fir pulpwood to 11.4 percent for hardwood fuelwood. High quality oak, on the other hand, increased 7.9 percent per year over the same time frame.

Roadside prices for medium quality eastern white pine increased at a slower rate than stumpage, approximately 1 percent annually.

The most common statewide average stumpage prices for eastern white pine logs in Maine are shown in Table 2 for the years 1977-1984.

Table 2.--Most Common Maine Statewide Average Eastern White Pine Stumpage and Mill Delivered Prices ($/MBF)

	Stumpage	Delivered
Spring 1977	40	
Fall 1977	41	
Spring 1978	46	
Fall 1978	50	
Spring 1979	56	158
Fall 1979	64	164
Spring 1980	64	164
Fall 1980	-	-
Spring 1981	61	163
Fall 1981	-	-
Spring 1982	75	165
Fall 1982	-	-
Spring 1983	70	167
Fall 1983	74	168
Spring 1984	75	173
Fall 1984	78	177

Source: Biannual Reports Utilization and Marketing Section of the Management Division, Maine Forest Service, Augusta, ME.

The overall trends in both stumpage and delivered values are much the same as in New Hampshire. The values are slightly higher in Maine, primarily for delivered logs. The stumpage values in Maine have also fluctuated slightly more than in New Hampshire.

The FOB mill, including wholesale commission prices, of Selects and Commons 1 X 6-inch kiln dry eastern white pine boards from October 14, 1983, to May 3, 1985, indicate the relative stability of the eastern white pine market. The November 1983 increase in the price of Selects and Finish grades parallels that of the increase in the structural lumber market. There was a 2-month lag in the increase of Premiums, and the lower grades, Standard and Industrial, have remained the same for the last 19 months.

Table 3.--Selects and Commons Eastern White Pine Kiln Dry 1 X 6 Boards ($/MBF, FOB Mill, Including Wholesale Commission)

	GRADES				
	Selects	Finish	Premium	Standard	Industrial
10/14/83	785	725	495	280	157.50
10/28/83	785	725	495	280	157.50
11/04/83	895	735	495	280	157.50
01/20/84	895	735	495	280	157.50
01/27/84	895	735	515	280	157.50
05/03/85	895	735	515	280	157.50

Source: The Commercial Bulletin, Marine Guide Publ. Co., Inc., Boston, Massachusetts.

The price of eastern white pine has been relatively stable. Prices do reflect major changes in the economy and market, but they are not as volatile as in the structural lumber market.

Wood Flow

Wood flow, the movement of eastern white pine logs from the landing to the sawmill, is worth noting. Statistics from Vermont show that from 1978 to 1981, 61 percent of the eastern white pine logs were processed within the county where they were harvested, 23 percent of the logs were processed in another county, 11 percent were processed in New Hampshire, and 5 percent were exported to Canada (Sendak and Bonyai 1983).

Of the 178.4 million board feet of eastern white pine sawlog production in Maine in 1981, approximately 0.6 percent was exported to Quebec, 0.3 percent to New Brunswick, and 0.1 percent to neighboring States. Maine also imported 11.6 million board feet of logs from other States, as well as 600,000 board feet from New Brunswick. Maine's eastern white pine total receipts for 1981 totaled 188.8 million board feet (Nevel, Lammert and Widmann 1985).

Blackmer (1985) reports that from 1978 to 1983, eastern white pine sawlog exports from Maine to Canada averaged 7 percent of the State's softwood exports, or approximately 20.8 million board feet annually. During the same period, Vermont exported on the average 700,000 board feet annually; and New York, 600,000 board feet.

Export-Import Trends

Table 4 lists the eastern white pine and red pine lumber exports for the years 1979-1984. Over this 6-year period, total U. S. pine exports averaged 46.8 million board feet annually, with an average FAS value of $12.5 million.

Table 4.--Eastern White and Red Pine Lumber Exports, 1979-1984

	Volume (MMBF)	FAS Value Basis ($ Million)
1979	46.1	13.6
1980	52.5	13.5
1981	61.8	15.8
1982	38.7	10.6
1983	43.8	12.0
1984	38.1	9.6
Average	46.8	12.5

Source: Prepared by the Forest Products Division, USDA Foreign Agricultural Service from US Department of Commerce, Bureau of Census Schedule B Commodity by County, FT 410, Monthly.

In 1984, eastern white pine and red pine exports totaled 38.1 million board feet. Rough lumber accounted for 23.1 million board feet and dressed lumber, 15 million board feet. Tables 5 and 6 show the primary destinations for those exports. Canada was the recipient of 66 percent of the 1984 pine export volume. Twenty-eight other countries accounted for the other 34 percent of the volume, or only 1.6 million board feet.

Table 5.--Eastern White and Red Pine Rough Lumber Exports, 1984

	Volume (MMBF)	FAS Value Basis ($ Million)	($/MBF)
Canada	18.5	3.9	211
Mexico	1.4	.3	206
Japan	.7	.2	323
Trinidad and Tobago	.7	.3	393
West Germany	.4	.2	639
United Kingdom	.4	.2	480
20 Other Countries	1.0	.5	211-760
Total	23.1	5.6	244

Source: Prepared by the Forest Products Division, USDA Foreign Agricultural Service from US Department of Commerce, Bureau of Census Schedule B Commodity by County, FT 410, Monthly.

Table 6.--Eastern White and Red Pine Dressed Lumber Exports, 1984

	Volume (MMBF)	FAS Value Basis ($ Million)	($/MBF)
Canada	6.6	1.4	211
Mexico	4.9	1.1	231
Trinidad and Tobago	.9	.3	347
British Virgin Islands	.6	.2	333
Netherlands Antilles	.5	.2	292
21 Other Countries	.6	.7	193-1,523
Total	15.0	3.9	263

Source: Prepared by the Forest Products Division, USDA Foreign Agriculture Service from US Department of Commerce, Bureau of Census Schedule B Commodity by County, FT 410, Monthly.

The FAS prices provided in Tables 5 and 6 should be considered for what they are, since they represent both eastern white and red pine, as well as a mix of products and sizes. However, they do provide some indication of relative worth. There is a wide range in values as illustrated by the values shown for the category, Other Countries, in Tables 5 and 6. This is particularly evident in Table 6 for the dressed lumber.

Import statistics for eastern white pine and red pine lumber for 1979-1984 are presented in Table 7. Import trends are more consistent than export. There has been a steady increase in pine imports over the past 6 years. Correspondingly, prices also have increased. This trend does not exist for the exports, as shown in Table 4. United States' buyers seem to be more consistent in their buying habits than their foreign customers.

Eighty-six percent of the eastern white pine and red pine lumber imported into the United States is from Canada, and 82 percent of the total imports are dressed lumber.

Table 7.--Eastern White and Red Pine Lumber Imports, 1979-1984

	Volume (MMBF)	Customs Value Basis ($ Million)
1979	106.9	26.8
1980	122.7	25.8
1981	249.9	47.0
1982	279.1	53.1
1983	333.8	63.5
1984	370.3	71.4
Average	243.8	47.9

Source: Prepared by the Forest Products Division, USDA Foreign Agriculture Service from US Department of Commerce, Bureau of Census Schedule B Commodity by County, FT 410, Monthly.

Summary

Eastern white pine will continue to be a desired commodity. Recent trends in pricing and wood flow indicate that white pine maintains, and even improves, its posture in the market place during down turns in the economy. It certainly has provided relative stability to the forest products industry in the Northeast.

Current markets are many and varied, but the domestic market will continue to be dominant. The export market offers limited opportunity.

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MORE VALUE ADDED FOR EVERYONE IN MARKETING EASTERN WHITE PINE

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Eastern white pine is the single most important commercial sawtimber species in New England. Pine lumber finds expanding long-term markets in the eastern megalopolis and in the southeast and midwest. Knowledge of pine sawtimber characteristics and specifically of the outside defect indicators is key to better utilization and management. Research results show that harvested trees cut up for grade, result in a higher grade product mix and improved returns to everyone in the marketing chain from the landowners to the ultimate lumber consumer. Today, when pine timber growth and harvest are very close, when incoming sawlog values exceed 50 percent of all inputs in lumber production, this long-available research on pine utilization assumes a new level of significance and may help to guarantee the future health of the pine lumber industry.

Most of the pine industry in New England is engaged in primary manufacturing with very little secondary processing. The value added to sawtimber occurs in the form of sawing, grading, drying, and planing of the material. Much effort and investment has been directed at adding value to the rough green product by creating a more differentiated dry-dressed graded product suitable for a wide range of year-round markets. The value added to pine logs by sawing them into rough green lumber can be anywhere from 50 to 75 percent. The value added by processing through drying, dressing, and grading may be 200 to 250 percent. The industry is successfully marketing pine lumber in the local markets and in the eastern megalopolis, Boston, New York, Baltimore, Washington and the midwest. The marketing committee of the Northeastern Lumber Manufacturers' Association is working on expanding markets for pine products even further.

I believe there is a greatly underestimated opportunity to add value to logs and subsequently to lumber by manufacturing logs to grade. Industry experience indicates that a conservative 10 to 20 percent can be added to the average rough green lumber value from the same number of trees cut.

It is important to understand the difference between grading logs and producing logs for grade. Grading logs is a process of appraisal based on specifications applied to cut logs, while producing for grade is the deliberate process of cutting up timber to grade specifications.

In my work as an Extension Specialist, I have visited a large number of mills and performed many mill studies. I have witnessed a serious lack of understanding or knowledge about the basic raw material, i.e., characteristics of trees and their natural defects. This lack of knowledge inevitably leads to a lower lumber product value. The potential value of any tree is seldom, if ever, recovered.

The basic product in most pine mills is "yard lumber", which is lumber produced to conform to the standard specifications established by the Northeastern Lumber Manufacturers' Association. Other products include: furniture grade lumber, timbers, log cabin cants, paneling, landscape ties and residues in the form of pulp chips, sawdust and bark. The relative value of these products is different. Each product has precise uniform specifications; yard lumber has the following:

1. Dimensions: length, width, thickness.

2. Presence or absence of specific NATURAL defects.

3. Presence or absence of specific MANUFACTURING defects.

4. Conditions with respect to moisture content and stain, and deformation.

All of these market specifications are adhered to rigidly, and lumber is sorted into different grade/value classes. The presence or absence of natural defects in lumber is generally random. In response to mill specifications, loggers often cut for long, straight logs or for mill-specified lengths, with emphasis on longer lengths and not the actual log grade potential (exceptions exist). Seldom is emphasis exclusively devoted to cutting logs for grade, although basic knowledge to do just that is available, using the research conducted by Myron D. (Mike) Ostrander, Robert L. Brisbin, and David L. Sonderman and others like Charles Lockard, Carl Newport and C.L. Vaughan.

The three most significant research publications on pine utilization are:

1. Ostrander, M.D., 1971, Identification and Evaluation of Defects in Eastern White Pine Logs and Trees. USDA Forest Service Research Paper NE-190, 27 pp., illustrated, NE Forest Experiment Station, Upper Darby, PA.

2. Ostrander, Myron D. and Brisbin, Robert L., 1971, Sawlog Grades for Eastern White Pine. USDA Forest Service Research Paper NE-205, 24 pp., illustrated. NE Forest Experiment Station, Upper Darby, PA.

3. Brisbin, Robert L. and Sonderman, David L., 1971, Tree Grades for Eastern White Pine. USDA Forest Service Research Paper NE-214, 30 pp., NE Forest Experiment Station, Upper Darby, PA.

This research deals with pine log grade specifications which allow the sorting of logs into distinctly different value classes with respect to the NELMA lumber grades. More importantly, the research also documents and defines outside log defect indicators and their significance with respect to the value of the logs in terms of NELMA lumber grade values.

For a variety of reasons, the significance of this research has never been fully appreciated and applied in the industry. This grading system was first developed for the U.S. Forest Service salvage crews on the National Forest after the 1938 hurricane. The system was originally used as an appraisal system for the sale of salvaged timber. Logs were primarily cut to standard log length, then graded and sold. Ostrander and Brisbin refined the original grades and upgraded the performance tables during the 60's. Long after the timber salvage was completed, Ostrander and Brisbin instructed at a multitude of log grading workshops organized by the Extension Services, Universities, State and Private forestry groups. The information was well received, and some improvement did occur in log-making practices by some of the attendees. However, there was no adoption of the grading system itself. This lack of adoption is believed to be due to the fact that there existed no overwhelming economic need for it. Timber was inexpensive and plentiful. The practice was to saw more timber to obtain the required amount of upper grades and set the low grade in the field to dry and then ship it to the box industry.

Today, the cost of logs delivered to the millyard is 50 percent or more of the average rough, green lumber value. Competition for sawlogs is keen, and production costs are high. Today, with profit margins declining, there is a REAL ECONOMIC need to recover as much value as possible from harvested timber.

Well-advised industry operators should not cut logs to arbitrary standard lengths just for straightness and length, <u>but</u> should institute practices to cut up harvested timber to produce logs of higher grade which will result in higher grade lumber.

In cases where timber was cut up to produce logs of higher grade, using a system adapted from the work of Ostrander and Brisbin, an increase in average product value of $10 to $25 per MBF was achieved with a concurrent upgrading of the product mix.

Some of the basic concepts useful in instructing loggers are:

1. Separate different defect types and sizes into separate logs.

2. Group like defects if possible, in the same log.

3. If possible, group all most-limiting defects into one log.

4. Produce grade logs instead of long logs in order to market higher grade lumber rather than length.

It is not the objective of this paper to present a course in log-making for grade. It is to suggest that on the basis of experience, every tree that is harvested can be cut for improved product value.

It is my conviction that today, on a daily basis, more value can be added to the product on the landing than in the sawmill.

I suggest that it is an area for serious consideration, as it addresses the utilization of the single most important commercial timber species in New England for which exists a steady and expanding long-term market.

I further bring to your attention that the technologists and researchers familiar with this work, for the most part, are retired or will retire soon, leaving no one behind to carry on. It is also unfortunate that most of the publications reporting this research are out of print.

Finally, I believe that useful research is going to waste. The net result is that, on most of the pine lumber produced in New England, at least $10 to $25 per MBF in product value (at the rough, green level) goes unrealized by everyone in the marketing chain. With pine lumber production estimated at over one half billion board feet per year, the unrecovered value by landowners, loggers and lumbermen is monumental.

Now, what can be done in New England to deal with this issue?

1. The pine industry that depends on this resource may take the initiative and consider collective action, through its association, to support and conduct a technology transfer program on this entire issue. Eventually this action may lead to an industry-wide set of "model log grades".

2. The pine industry collectively, through its association, may consider supporting a technology transfer program on this subject using a mechanism involving state universities, the Extension Service, state Forestry Departments, consultants, task forces, or possibly the formation of a Regional White Pine Institute.

3. The pine industry, through its association, may collectively request the U.S. Forest Service to update and reprint the research results on this subject.

4. The pine resource is changing, and further research in this area is indicated. Industry may formulate special research projects for USFS funding.

5. Forestry schools may consider teaching and initiating research on this subject.

Implementation of such a program, with continuity over time, has the potential of benefiting everyone in the region with the major benefits to the landowners, loggers and the lumber industry, and assuring continuity of supply of domestic quality lumber to the consumers.

A successful technology transfer program resulting in the increase in the average grade mix of the lumber marketed in the region will not only increase the revenues to the individual mills, but will also make eastern white pine a better product and increase its competitive position with respect to lumber from other regions.

SOFT PINE FOR THE FUTURE

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During most of this century, eastern white pine has suffered in competition with supplies of similar wood that now come mainly from the dwindling reserves of old-growth in the West. When soft pine must be grown deliberately, the intensive culture of eastern white pine will become one of the best options. However, it will be necessary for more forest owners to start the pruning and thinning that will be needed to produce adequate supplies for the development of a processing industry based on wood of good quality.

Present Sources

We should not think just in terms of "eastern white pine" but of "soft pine" instead because that is really the humanly desired commodity being produced. White pine has been used for many purposes but its best and most ancient role is as a soft, low-density wood that is easily worked and dimensionally stable with respect to changes in moisture content.

During most of the 20th Century the demand for such wood has been filled mainly by the soft, fine-ringed, outer-rind wood of old-growth conifers in the South and West. This includes much from western white and sugar pines. One example was widely advertised in the 1930's and 1940's. It was "Arkansas soft pine" which was, not a contradiction in terms, but the outer-rind wood of old loblolly and shortleaf pines. However, this kind of substitute for white pine was so much a product of virgin forests that it is not likely that many Arkansas foresters would recognize the term today.

In the West, many mills produce this kind of fine-ringed lumber from such species as ponderosa pine and Douglas-fir. Everyone likes to sell such wood but few seem ready to invest in the very long years of almost negligible growth that are necessary to produce it. With the 5-needled pines this kind of material is produced by all trees regardless of age or rate of growth. The end of the supply of superb wood from ancient western 5-needled pines is in sight. In fact, the standing volumes of these species cease to be much greater than those in the east. However, the statistics from the East mix red and white pine and include much eastern white pine of poor quality. On the other hand, there are some problems of growing the western species that make those with eastern white pine seem small. The blister rust is a greater threat; the terrain is often adverse and the competing vegetation is fully as aggressive.

Prospects in the East

This kind of soft wood has been a North American money commodity longer than almost anything except salted fish. It was first produced in the eastern part of the continent and its production has continued here for more than three and a half centuries. When society wants to grow this kind of wood rather than just depend on finding it in the forest, this is the region, *Pinus strobus* is the species, and the time to start is now or yesterday.

If the opportunities are to be grasped in ways that are economical for land-owners there are some things that need doing. There is no way of producing good white pine without some long-term silvicultural investment in such steps as hardwood control, pruning, and early thinning. The amounts of investment are in total no different from those commonly made in planting and growing Douglas-fir for framing timbers that command much lower prices per thousand board feet. Furthermore, the big investment in growing good white pine is artificial pruning which comes much later in the rotation than planting and does not have to be carried at compound interest so long.

The investments are attractive only if rapid diameter growth can be secured. It is not possible to do this by following conservative thinning schedules that are based on the premise that the object is to maximize cubic volume production, especially if much of that production is in loose-knotted lumber. There is nothing fundamentally wrong with stocking guides. Among other things they give us the courage and assurance that is necessary to thin hard enough. However, they should be based on known and definite economic criteria; not the least important of these is the rate of compound interest return on the investments involved in any kind of timber growing.

The lumber industry also needs a critical mass of good material on which it can operate and base the necessary processing facilities. If there is no adequate supply of good pine logs there is no stimulus to base log or stumpage prices on log quality. The market system is not capable of pricing something which does not appear on the market. There is a dilemma here. So long as timber-growers, such as I, leave most pruned pines standing in the woods because they are still growing well, we cannot expect the market to recognize either their value or their existence by putting a price on their high potentialities.

Growing good white pine is as good a long-term investment as there is in timber management. If a significant proportion of land-owners start pruning and thinning now the times will change enough over the next 35 years to make it a good idea. The next 3 years may be enough but it will take longer to grow the tree to sawlog size. There is far more risk that there will not be enough than that there will be any price-depressing surplus. We do not necessarily have to plant white pines to start because there are plenty of good stems in the forest waiting to be treated.

FACING REALITY

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ABSTRACT

State Forestry Agencies are called upon by the general public to play an exemplary role in managing private and public forestland. Tight environmental constraints, increasing cultural costs, a need for softwood-roundwood markets, a shrinking land base and the fact that on many sites white pine's ecological role is early successional, are only a few of the challenges that must be met in order to perpetuate the eastern white pine forest type in the northeast. It is the intent of this short presentation to briefly expound on the challenges facing state agencies of urbanizing states such as Massachusetts and the need for a cooperative effort to develop and manage the white pine resource.

TEXT

Most state forestry agencies have statutory responsibility for state and private woodlands. In the small urban-industrial state of Massachusetts, service foresters render technical assistance to non-industrial private owners who control over 2.5 million forested acres; state lands foresters direct management on nearly 350,000 acres. Of course, many of these woodlands either do or could support crops of eastern white pine.

Short-sighted land management practices in the past have led to the development of many volunteer hardwood stands on sites that are ill-adapted to support them. The classic example of this mis-match is the poor quality hardwoods growing on acreages more suited to eastern white pine. This site-species mis-match: provides unbroken habitat for gypsy moths and other defoliating insects; significantly reduces volume production, and; lessens quality of the timber.

Because of this, it is difficult or impossible for landowners to realize a profit from managing these timber stands. In essence, the site/species mis-match is a disincentive to forest management and an incentive for withdrawing land from the already dwindling resource base. Unfortunately, many of these lands are reallocated to uses that return higher profits.

We would like to make it clear that we are not advocating a large-scale dedication of land in the urbanized northeast to the exclusive culture of white pine (similar to the plantation culture undertaken in the southern and southeastern U.S.). The variability of glaciated terrain coupled with small woodland ownerships would preclude such an approach. However, there are many situations that lend themselves to white pine conversion.

After listening to the speakers over the last two days and offering a few suggestions of our own, it has become apparent that the real problem is not a lack of knowledge, but a lack of resources to carry out what must be done. Perhaps the real problems we face are socio-political not biological. Whatever the case may be, we as a profession have not been able to loosen necessary purse strings to put into practice much of what we already know. Given that we will have to deal with limited financial resources in the future, it follows that for white pine cultural practices to be readily accepted and implemented, we believe they must be practical, affordable and of a low-technology nature.

Obviously, in order to manage eastern white pine it must first be established. Based on this premise, we have narrowed our comments principally to its establishment.

In existing pine stands or in those where Pinus strobus is a component, natural regeneration is probably most desireable. However, to be successful certain factors must be overcome. Controlling insects that retard seed production is surely a challenge. Are practical low-cost methods to monitor and control these pests available? If not, are they being developed? Furthermore, the infrequency of white pine seed crops and the recent media attention paid to induced multiple births in humans makes us wonder if this species would respond to a hormonal application developed to stimulate and control seed production. Are such biochemicals being developed?

Where no seed source exists on a site suitable to support P. strobus, artificial regeneration methods must be utilized to establish it.

Planting of conventional bare-root stock is relatively expensive and unaffordable to many landowners. Container grown seedlings or "tubelings" hold promise. But, they or the necessary special planting equipment are not readily available. Perhaps, we as state forestry agencies should take a lead demonstration role in using this technology on public lands. Would it be helpful to lease the specialized equipment to clientele at a nominal cost and to supply superior planting stock?

Not so long ago direct seeding held promise as a means of establishing eastern white pine in New England. Probably the chief reason for shelving this practice was EPA's ban of chemical repellents for minimizing seed predation by small mammals. Direct seeding still holds promise. For the affordable sum of $90.00 one can purchase a Panama direct seeder. This device weighs only 7 pounds, burns no gasoline and has very few moving parts. Together with a few pounds of genetically superior seed one can easily and quickly regenerate several acres of land.

To supplant chemical treatment of seed, researchers could develop schedules for pregerminating white pine seed in order to minimize the field

exposure to predation. At planting time pregerminated seeds should be well on their way to sprouting but not so far along as to be damaged during handling and seeding.

Site preparation is usually necessary for successful artificial and natural regeneration. The use of prescribed fire has been suggested as a site-prep tool. Our experiences with air-quality agencies have not been reassuring. Moreover, herbicides, while proven to be effective in controlling competing vegetation, are not at all popular with the general public. Therefore, it seems that a practical alternative is some mechanical method of site-preparation. Though Marden drum choppers, Rome harrows and other heavy scarifying devices do a good job of site-prep, they are costly to buy, operate and transport.

Since most of our harvesting operations employ rubber-tired skidders, why not adapt them for site preparation/scarification? Conceivably, rake teeth simply bolted onto a skidder's blade would accomplish the necessary work. Since the machine is already on the site let's use it for site-prep work!

Historically, the white pine box-board business of the early 1900's formed the basis for Southern New England's present lumber industry. Though production has dropped considerably from that bygone era, white pine remains the region's most important softwood. If it were possible to implement all of the suggestions presented at this symposium for improving white pine's quality, a greater portion of the market, now dominated by western softwoods, could be recaptured. Good markets must be made available to financially reward those who invest in the intensive culture of white pine and other native commercially valuable species. We suggest that the promotion of eastern white pine and other native lumber at the retail level is one means of increasing product value, some of which would filter down to the forest owner in higher stumpage prices.

As stated earlier, our greatest problems are more socio-political than biological. While some of our suggestions relate to reducing the cost of cultural operations we still need the human and financial resources to carry them out. The profession's greatest challenge, as it has been in the past, is that of salesmanship. We must convince both private landowners and those who control public monies that white pine culture is a good investment from a financial and multiple-use standpoint.

AN INDIVIDUAL PERSPECTIVE ON WHITE PINE MANAGEMENT

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The real challenge of growing white pine lay not in its silviculture, but rather in matching its silviculture to a landowner's objectives. Small woodlot size, short time horizons of woodlot owners, competing uses for the land and lack of a strong management ethic present the real difficulties.

My perspective to the issues of white pine management comes from working with private woodland owners in Hillsboro County, the most populated county in the state of N.H. The average size woodlot I visit is approximately 45 acres, but have ranged anywhere from 1 to 1500 acres. Those of you familiar with Extension forestry in N.H. know that along with other goals, our major emphasis is to encourage woodland management through education, primarily on a one-to-one basis on the woodlot.

In a state that is 86% forested with the majority of that forested land in small private ownerships, the impact of the private woodland owner on the white pine resource is important.

We have spent our time at this symposium discussing the technical means of growing white pine. I would now like to consider the social means of growing that tree. While its silviculture presents difficulties, matching silviculture to a landowner's objectives is what presents me, and I suspect you, with the real challenges.

A major problem I face trying to effectively manage for white pine is small woodlot size. Managing small woodlots intensively is not always economical, but then that is not news to you. Cliff Foster has already assured us that this is not an insurmountable problem. To a large extent, I agree with him.

A more significant problem in managing for white pine on privately held woodlots is time. We foresters talk about 100 year rotations, while our clients think ten, maybe twenty, and if we are lucky, more years of ownership. I find it relatively easy to convince an owner to do an improvement, selection, or shelterwood cut or any number of intermediate thinnings that will result in income. Landowners are even willing to make sacrifices in larger immediate returns from a cutting to improve their woodlot for future generations. It is, however, far more difficult to convince them to convert a site growing poor quality hardwoods to pine, to prune, to do pre-commercial thinnings; in short, to make an out-of-pocket investment for a return they will never realize. It is easy for me from both a forest management and a people management standpoint to increase growth of existing stands. It is far more difficult from both standpoints to establish reproduction and bring it through its pre-commercial years.

Many studies have indicated that the majority of private woodland owners do not own woodland for economic return. They indicate that the primary reasons for owning land are for other amenities - wildlife, aesthetics, recreation, and just knowing it is there. My experiences tell me that when "push comes to shove", as it so often does, the financial value of the timber and the timberland becomes of over-riding importance and the difference between what is said and what is done is vast. This reality of the actual behavior of our private woodland owner should not be over-looked. Frequently, the owners of our resource go directly from non-management to poor management. The so often cited amenities for owning land become a reason for doing nothing until a personal financial crisis, a convincing individual knocking at the door, or a dramatic upswing in the market conditions encourage the landowner to cut and sell, frequently in a haphazard manner. Too much timber is sold in this manner without professional assistance. Much of our white pine resource is lost to crisis management instead of renewed through timber management.

I would argue that poor, or no, forest management, for whatever reason, is better for our resource than is the frequent alternative. My county of Hillsboro is the most populous and among the fastest growing in the state. It includes the cities of Manchester and Nashua. Many of our towns serve as bedroom communities to these cities as well as to the greater Boston area. The sandier soils in the southern and eastern parts of the county that grew our best quality pines, now grow our most expensive houses.

For me, these problems, small woodlot size, short time horizons of our woodlot owners, competing uses for our best pine land and lack of a strong management ethic among our owners are the most difficult aspects of white pine management. However, there are other obvious problems with using some of the intensive management techniques we have discussed at this symposium. While fire, insecticides, and herbicides have a place in the forester's book of white pine management, woodland owners and the general public resist these techniques, especially in a suburbanizing area such as Hillsboro County. While buying logs based on grade makes sense for our white pine mills, and someday may act as a strong incentive for our landowners to manage for quality, the lack of uniformity within the industry does not now encourage managing for quality as much as it

encourages confusion. While pruning increases the quality of the lumber recovered for the mill, this has yet to translate into significantly higher stumpage prices for the woodland owner, at least in Hillsboro County. To be fair, this may partly be due to the small amount of pruned pine actually available on the market.

We have adequately addressed some of our more difficult technical questions these past three days and while I have raised some difficult social problems impeding the management of white pine, I have yet to offer solutions. As you may have guessed, I have none, or at least none that are definitive or easy.

I feel we need to continue with and improve on some of the methods we now use as well as introduce new methods. We need to continue with a mix of public, industrial, and private consulting foresters offering professional advice and services. We need continued financial assistance to help woodlot owners make investments in pre-commercial work that will give benefits in the future. We need an industry that rewards managing for quality by using a more uniform log grading system. We need to continue with current use property taxation to make holding land for forest management economically possible. We need to consider more aggressive land protection efforts such as conservation easements and the sale of development rights. We need continued efforts in the public and private sector to educate our public about who we professionals are and what we are trying to accomplish. We need to better educate our public about the technical aspects of our field, but more importantly, we need to better educate them in our ethic. Even if all the economics to manage makes sense, it may be the stewardship ethic alone that will motivate. In instances where management makes no economic sense for the individual, it is the only thing that will motivate.

WHITE PINE IN THE SOUTHERN APPALACHIANS

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This area extends along the Appalachian Mountain chain within the natural range of white pine. It occupies an estimated 35 million acres and includes parts of West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, and Georgia. A survey of the six National Forest Silviculturists in the affected area indicates that the species grows best at elevations of 2000 to 3000 feet. Except in isolated cases, insects and diseases are not a serious management problem. White pine should be grown on sites with a site index of 40-65 for upland oaks - 3 of 6 respondents narrowed this range to 45-60. These sites represent 13% of the manageable land base on these forests and if expanded to the total forested land base within the natural range, white pine should be a management consideration on an estimated 3 million acres. The most common practice in establishing white pine is site preparation, plant 200 to 300 genetically improved seedlings and release 100-200 seedlings 2-5 years after planting. With the exception of one forest, almost no advantage is being taken of natural regeneration. There are few silvicultural problems in managing the species. The market for white pine sawtimber is good with stumpage values ranging from $50 to $90 MBF, averaging $65 in the affected area. Most foresters prefer to manage the species in pure stands, but there is strong public opposition to growing conifer in pure stands. A closer look at economic and wildlife values would, in our opinion, show higher total values produced by managing the species in mixed stands.

EASTERN WHITE PINE IN THE SOUTHERN HIGHLANDS

Daniel H. Sims

Forester
Southern Region,
USDA Forest Service
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Atlanta, GA 30367

Abstract

Eastern white pine (Pinus strobus L.)is rapidly gaining popularity in the southern highlands. Demand has strengthened for relatively small logs with sound knots, especially for furniture. An optimum management strategy will aim for harvest of the small sawlogs most in demand, when trees are 35 to 40 years old.

Loblolly, slash, longleaf, shortleaf--these are the southern pines, right? Right! These are the southern yellow pines, so important to the economy of the South. They account for a lion's share of the raw material which, in just one state, Georgia, feeds a $6 billion forest-related industry (Montgomery and Chaffin (1982). The general demand for, and ubiquitous nature of, the yellow pines and southern hardwoods tends to overshadow the considerable potential for other species. Eastern white pine, in particular, has the potential for unequaled growth and development in the Southern uplands.

White pine has gained in popularity recently, particularly in the manufacture of pine furniture. White pine accounted for an estimated volume of 135 million board feet purchased by eastern furniture manufacturers during 1982-83. About half of this volume was purchased by manufacturers in the South (Smith 1984). Improved markets and a preference for smaller trees with small sound knots offer a prime opportunity for management of white pine.

In the South, white pine grows in portions of the Appalachian Highlands; Valley and Ridge; Blue Ridge physiographic regions; the western piedmont of Virginia, North and South Carolina and the northeastern piedmont of Georgia (Fig. 1). Eastern white pine commonly occurs at elevations ranging from 1,000 to 4,000 feet. It does best on northern and eastern slopes and stream terraces between elevations of 2,000 to 3,000 feet.

The latest forest survey data for the five South Atlantic States and Tennessee estimates just under 1/2 million acres in the white pine/hemlock type, with sawtimber volumes of about 4.8 billion board feet. The potential for expanding the white pine resource is several times greater than these figures.

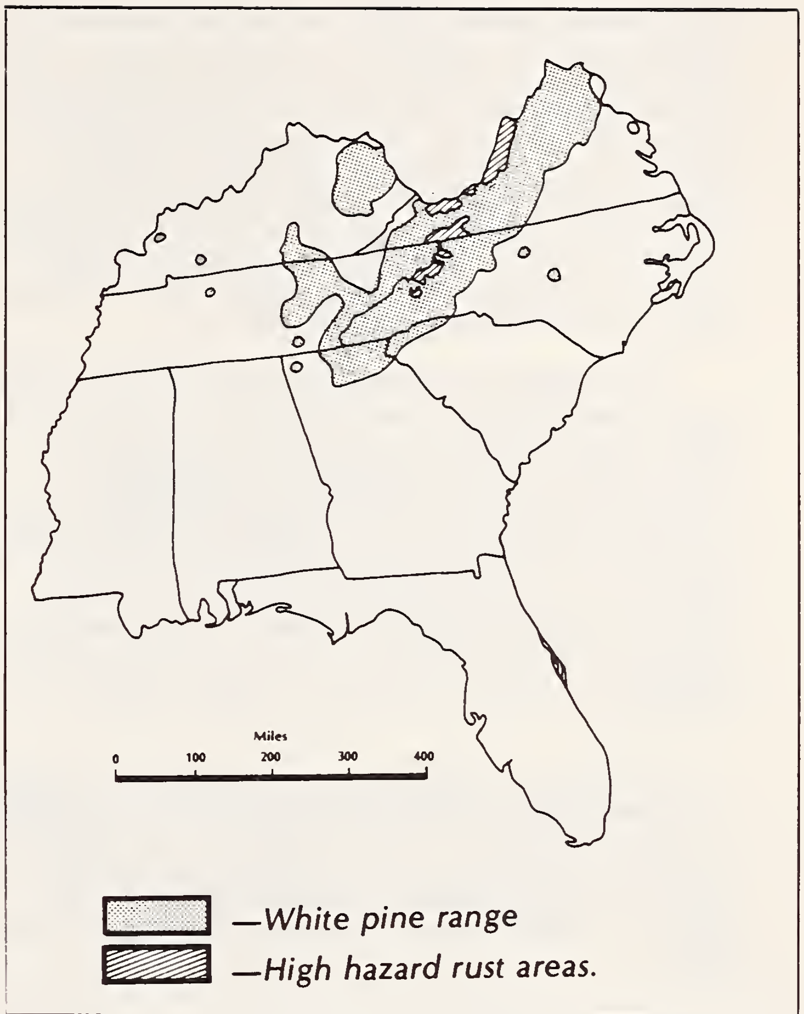

Figure 1—Distribution of eastern white pine in the South, and high hazard areas.

White pine grows on a wide range of soils and sites, with best development on moist, alluvial soils along rivers and streams. As is true in the other parts of its range, white pine in the South, with proper management, will yield a higher volume of timber on a given site than will its associated species. The comparative site index for white pine is higher on all the sites except the very best, where only yellow-poplar is superior in height growth (Doolittle 1958). Diameter growth and yields are higher for white pine across all sites. Some sites, however, may be less suited to white pine than other species. These sites include some seriously degraded sites, heavy clay soils and very poorly drained sites.

Given careful attention to the silvical characteristics of white pine, which have been well covered in this symposium, the species is a logical choice for intensive management over a large area of the Southeast.

Regeneration

The option exists for natural or artificial regeneration in some areas. In others, particularly where you must convert or recapture white pine sites, planting is necessary. The shelterwood system is the most widely used and the most versatile method of natural regeneration. The seed-in-place regeneration method also works well.

The periodic seeding habits of white pine require coordination of treatments with seed crops. Logging should start after the mid-August seed-fall and end before seed germination the following May. Because of their slow start, seedlings usually need release from competing hardwoods about the fourth growing season. Glyphosate, applied after the period of rapid growth, is a promising herbicide for vegetative release in the South. See the label for specific instructions on the proper timing and related directions for use.

Herbicides and prescribed burning, both singly and in combinations, have proven an effective site preparation practice for planting white pine. Particularly where rhododendron (Rhododendron L. Sp.) and mountain laurel (Kalmia latifolia L.) are a problem, treatment with a herbicide between May 15 and June 15, followed by prescribed burning, is effective. Two-year-old white pine seedlings should be planted after February 1 on burned areas to minimize freeze problems. Burns that remove a minimum of surface litter and logging debris are desirable.

Because white pine will tolerate considerable shade when young, underplanting followed by release is another option. This practice has not been widely used in the South, but is promising in low-quality hardwood stands with moderate overstory stocking. Seedlings will need release after a few years.

Growth and Yield

Plantation growth and yield are strongly influenced by initial spacing and site quality. Growth rates of 3 cords per acre per year on average sites and up to 6 cords on the best sites may occur on closely-spaced plantations between 20 and 25 years of age. Early board-foot yields are much greater in plantations with wider spacing. Board-foot growth and yield is probably maximized at spacings of 12 by 12 feet or slightly greater. At that spacing, average sites can produce 600 to 800 board-feet per acre per year on a 35-year rotation (Balmer and Williston 1983).

Insects and Diseases

In the Southeast, white pine is relatively trouble free when compared to other southern pines and to white pine in some other regions.

So far, the white pine weevil (Pissodes strobi) has only been a limited problem in the Southeast. Shelterwood regeneration is an option where this problem exists. Four other pest problems, listed in order of importance, are (1) root decline caused by a fungus, Verticicladiella procera, (2) air pollution caused by ozone (O_3) and sulfur dioxide, (3) annosus root rot caused by a fungus, Heterobasidion annosum, and (4) white pine blister rust caused by a fungus Cronartium ribicola.

White pine blister rust is best avoided by not planting these pines on the highest-risk sites (Fig. 1). These sites are above 3,000 feet in elevation, may have abundant Ribes, an alternate host, and diseased trees are present (Anderson and others, 1980).

The pales weevil (Hylobius pales Herbst) is the most serious insect pest of pine reproduction in the East (Speers and Rauschenberger 1971). This pest can be a problem if planting follows too closely behind harvesting. Harvesting should be completed before July 1, or planting postponed 1 year on areas harvested after July 1.

White pine is preferred over other pines by the introduced pine sawfly (Diprion similis Hartig). The great number of eggs laid on white pine and high survival of the larvae contribute toward making white pine the most injured species (Wilson 1971).

Management Strategy

This strategy is based on current market trends. Demand for white pine cordwood in the South is limited. Management for earliest sawtimber production with short rotation makes more sense for the foreseeable future. Accordingly, 300 to 500 trees should be planted per acre. Spacing of trees should be about 12 by 12 or 10 by 10 foot, or the equivalent.

Thinning opportunities will depend on local markets for small logs. Thinnings at about age 20, and 30 at the higher densities, might be possible. Thinnings may not be needed at the lower densities because studies show that about 350 trees per acre will reach 9.5 inches in diameter at breast height (minimum sawtimber size). For the furniture market, final harvest should be made around age 35 to 40 because relatively small logs with sound knots are most in demand.

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NATURAL WHITE PINE REGENERATION: SITE REQUIREMENTS

Kenneth Sloan

Forester
Wisconsin Department of Natural Resources

Steven Heckman

Silvicultural Forester
Menominee Tribal Enterprises

Marshall Pecore

Forest Manager
Menominee Tribal Enterprises

Abstract

This poster will highlight three important site requirements related to natural white pine regeneration:

Site Evaluation - A Habitat Type Classification System used in Michigan and Wisconsin will be presented. Productivity, successional trends, and tatum guides for field application will be displayed.

Scarification - A slide/tape program on patch scarifiers will be presented. The program will discuss what machinery is available, what it looks like, what it does, and how it is used in white pine natural regeneration.

Crown Density - An instrument for measuring percent crown density will be set up and demonstrated.

MONONGAHELA NATIONAL FOREST - CLOVER RUN WHITE PINE PLANTATION

G. W. Wendel - H. Clay Smith

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Timber and Watershed Laboratory
Parsons, WV 26287

Abstract

The "Clover Run White Pine Plantation" was established in the spring 1933 on the Monongahela National Forest near Parsons, West Virginia. White pine was planted at a spacing of 6 x 6 feet in alternate double rows with yellow-poplar, European larch, and Japanese larch. One part of the plantation was planted to pure white pine. None of the co-planted species have survived.

At 51 years, there is an average of 44 mbf/acre in the plantation. Many of the dominant trees in the stand exceed 125 feet in total height. Average stand diameter is 18.8 inches. A series of thinnings and salvage cuttings beginning in 1953 have removed 17 mbf per acre. Average annual growth during the past 20 years is about 1.7 mbf per acre.

In 1948, 1958, and 1960, some of the best trees were pruned to 17 and 24 feet.

Fomes annosus root rot was discovered in 1959. Stumps in the 1960 thinning were treated with creosote and in the 1966 thinning, stumps were treated with Borax in an attempt to control the spread of the disease. *Fomes* has declined since 1966 and no stump treatments have been applied since 1971. At present, the residual stand appears to be vigorous and healthy.

FERTILIZATION OF WHITE PINE IN MAINE

Robert K. Shepard - Thomas B. Brann

College of Forest Resources
University of Maine
Orono, ME 04469

Abstract

A fertilization study of eastern white pine (Pinus strobus L.) was initiated to answer the following questions; (1) will a growth response occur? (2) what treatment(s) will produce the largest response?, and (3) will increases in growth that may occur be large enough to make fertilization an attractive cultural practice?

Plots were, and are still being, established in white pine stands at numerous locations in Maine. Treatments applied to the first group of stands consisted of nitrogen at rates of 50, 100, and 200 lb/acre, phosphorus at 30 and 60 lb/acre and potassium at 40 and 80 lb/acre as well as combination treatments in some stands. Analyses of dbh measurements made two years after treatment indicated that where response occurred, it was due primarily to nitrogen. Subsequently, emphasis was placed on determining the most desirable application rate and the economic feasibility of nitrogen fertilization.

Seven stands that have completed four growing seasons since treatment showed the largest increase in basal area growth, 0.034 ft ^{2}/tree, at an application rate of 100 lb of nitrogen/acre. The increase at 200 lb/acre was 0.013 ft ^{2}/tree; 50 lb/acre produced no response.

Response to 100 lb/acre was greater in southwestern Maine than in southcentral Maine (0.040 ft ^{2}/tree vs 0.027 ft ^{2}/tree). Moreover, southwestern Maine stands responded more during the first two-year period than during the second, whereas in southcentral Maine the reverse was true.

The estimated increase in volume at 100 lb/acre was 1,100 bd ft/acre. With an estimated total fertilization cost of $45/acre and stumpage prices of $100 and $80/thousand bd ft for high and average quality stands respectively, real rates of return averaged 19 and 11 percent. The increase in volume was reduced by 20 percent before returns were determined to compensate for the phenomenon of "growth response falldown."

1/ This research was funded by the Cooperative Forestry Research Unit, College of Forest Resources, University of Maine, Orono 04469.

REGENERATION PATTERN OF EASTERN WHITE PINE (Pinus strobus L.) IN A THREE HECTARE MIXED SPECIES STAND

Peter R. Brym and R. T. Eckert

University of New Hampshire
Durham, NH 03824

Abstract

Regeneration of eastern white pine (Pinus strobus L.) is of interest to foresters in northern and central New England. The objective of this study was to evaluate the recent regeneration patterns of eastern white pine in a mixed hemlock-pine-hardwood stand near Durham, New Hampshire.

Age of 132 randomly selected eastern white pines was determined in a three hectare stand containing a total of 1000 eastern white pines. The location of trees in different age categories was mapped to show distribution of even-aged eastern white pines.

Clustering of white pines into distinct geographical groups increased with decreasing age of members. The results indicate that recent eastern white pine regeneration in this stand occurs in small groups, as described by Hibbs (1982). The observed patterns may be due to recent canopy disturbances in the predominantly hemlock and white pine dominated canopy of the stand.

THE WHITE PINE TREE IMPROVEMENT PROGRAM AT THE MAINE STATE FOREST NURSERY, GREENBUSH, MAINE

Kathy J. Nitschke

Tree Improvement Specialist
State Forest Nursery
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Passadumkeag, ME 04475

Abstract

This series of posters illustrates the development of the white pine tree improvement program at the Maine State Forest Nursery, Greenbush, Maine. Clonal seed orchards are the end product of the program, producing improved seed for use at the nursery. This is to be accomplished in three phases - Phase I - plus-tree selection; Phase II - Clonal propagation; and Phase III - seed orchard establishment.

GROWTH AND SURVIVAL OF UNDERPLANTED WHITE PINE, RED OAK, AND WHITE OAK SEEDLINGS

James E. Johnson

Associate Professor of Forestry
College of Natural Resources
University of Wisconsin - Stevens Point
Stevens Point, WI 54481

David W. Smith

Professor of Silviculture and Forest Soils
Department of Forestry
School of Forestry and Wildlife Resources
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

Abstract

Problems with the adequacy of natural regeneration following harvest cuts in predominantly oak stands has led to the investigation of underplanting as a means of establishing advance regeneration prior to cutting. Northern red oak (Quercus rubra L.), white oak (Quercus alba L.), and eastern white pine (Pinus strobus L.) are all of intermediate tolerance and are known to survive and compete with other plant species in partial shade. This study was undertaken to evaluate the survival and growth of underplanted seedlings of these three species. The study area was located on the Reynolds Research Station in the Piedmont of south-central Virginia. Twenty-nine regeneration plots were established under a variety of forest canopies (20 hardwood overstories and 9 pine overstories), and 15 seedlings of each species were hand-planted at a 3 m x 3 m spacing on each plot. Seedling height in cm and root collar caliper in mm were recorded at the time of planting and after the first, second, and third growing seasons. After three seasons in the understory, white pine survival was 58%, white oak survival was 57%, and red oak survival was 37%. White pine out-performed the oaks in both height and diameter growth. Three-year height growth for white pine was 16.4 cm, significantly (0.05 level) greater than the 7.5 cm recorded for white oak, which was significantly greater than 6.0 cm of red oak height growth. Three-year root collar diameter growth for white pine was also significantly greater than for the oaks, 1.61 mm for white pine, 1.07 mm for white oak, and 1.01 mm for red oak. Die-back of tops followed by sprouting was more common for white oak than red oak, however, both height and diameter growth of sprouts was greater for white oak. Regression analysis showed no significant relationship between overstory basal area and seedling survival or growth. White pine appeared to be a better species for underplanting based on the results from this study, however, future studies will focus on the survival and growth of these seedlings following removal of the overstory.

THE RESPONSE OF IMMATURE WHITE PINE (PINUS STROBUS, L.) TO THINNING

A. R. Gillespie - H. W. Hocker, Jr.

University of New Hampshire
Durham, NH 03824

In examining the response of immature white pine to thinning, no significant difference in eight-year net basal area production was indicated between three treatments; (A) thinning to B-line stocking; (B) thinning to release approximately 80 crop trees per acre (200/ha); (C) controls. The plots, located in six stands in southern New Hampshire, produced an average of 45 square feet of basal area per acre (10.43 square meters/ha) in eight years regardless of treatment. Accelerated growth of trees in thinned plots was evidenced by their significantly greater increase in mean stand diameter for the eight year period. When examined by diameter class, four, six, eight and ten inch trees on thinned plots showed more basal area growth than controls. No significant difference was seen between treatments for twelve inch trees. B-line thinning gave greatest response over controls in the four inch size class. Crop tree thinning showed best response over controls in the eight inch size class, the average crop tree size. Though no significant difference in basal area production was seen between treatments, the six stands differed in basal area production. However, stand production did not correlate with stand density. Differences in production were attributed to site characteristics.

WHITE PINE GROWTH MECHANISMS AND SITE DETERMINENTS

Alan C. Page

Green Diamond Systems
125 Blue Meadow Road
Belchertown, MA 01007

Abstract

There are two carbohydrate allocation mechanisms within the white pine tree that are of basic importance to the economic management of a white pine timber crop. This poster will document these mechanisms, present a site classification system, suggest appropriate stocking levels for economic stand management at a fifteen percent alternative rate of return, and discuss why the maintenance of tree health requires early attention.

A five-page summary of the poster presentation is available from the author.

EASTERN WHITE PINE FOR SURFACE MINE RECLAMATION

Walter H. Davidson

Research Forester
Northeastern Forest Experiment Station
Princeton, WV 24740

Abstract

Eastern white pine has several characteristics which make it a desirable species for surface mine reclamation. It is native to the Appalachian and Northern Interior Coal Fields. Past experience has shown it is well adapted to a wide variety of soil types and climatic conditions. It is more shade tolerant than many of the other species being used for reclamation. Thus it has a better chance of surviving when planted in mixtures with herbaceous species. Comparatively slow seedling growth has discouraged the use of white pine in many areas. However, its rapid juvenile growth more than compensates for the slow start. A review of white pine performance on several mine sites in Pennsylvania, West Virginia, Kentucky, and Ohio illustrates its potential as a preferred reclamation species.

STEM QUALITY OF WHITE PINE - DIRECT SEEDED IN FURROWS vs. CONVENTIONAL PLANTING

Raymond E. Graber

USDA Forest Service
Northeastern Forest Experiment Station
Durham, NH 03824

Abstract

An eighteen-year-old eastern white pine (Pinus strobus L.) stand, that has been direct seeded on an old field, is compared with a 6- by 6-foot plantation of the same age and seed source. Direct seeding resulted in a tree population more than three times larger than that of the plantation. The seeded trees had smaller branches and fewer, less serious weevil injuries than the plantation. The better quality stems of the seeded pine are largely attributed to the higher density of that stand. Costs of direct seeding are estimated to be less than one-quarter of conventional planting expenses.

MODELLING INDIVIDUAL TREE RESPONSE TO THINNING

A. R. Gillespie - H. W. Hocker, Jr.
University of New Hampshire
Durham, NH 03824

Abstract

Though thinning redistributes stand growth, accelerating growth of residual trees, this redistribution is not equal. Slow and fast responses are seen, though average response rates are most often greater than those of unthinned stands. This study examined variation in individual tree growth response and its cause. Ninety trees of five size classes were selected from two white pine stands in southeastern New Hampshire. Trees were selected for each size class (4-12" DBH) from the upper and lower third of a percent diameter growth response gradient.

Regression analysis was used to determine best fit models for eight-year absolute and percent growth in diameter, basal area, volume and height. Independent variables tested were percent competition, calculated from overlapping tree zones; crown class; percent live crown; size class; age at thinning; growth before thinning; the allelic patterns and heterozygosity of three chromosome loci determined using horizontal starch get electrophoresis. Variables found significant in predicting post-thinning growth were competition, crown class and size class. Diameter growth decreased with increasing competition and crown suppression. Equations for basal area and volume growth were similar. Competition was not significant in predicting height growth.

In addition, seasonal growth patterns were examined using band dendrometers and found similar to eight-year periodic growth. For the 1984 growing season, dominant trees and trees with little competition grew faster, started growth earlier and grew later into the season. Growth was slower, started later and ended earlier as trees became more suppressed. Within a crown class, seasonal diameter growth decreased as competition increased.

The results of this study indicate that competition is the most important variable controlling individual tree growth response.

EFFECT OF HEAVY DEFOLIATION BY GYPSY MOTH ON WHITE PINE SURVIVAL AND GROWTH RATE

Thomas M. ODell

USDA Forest Service
Center for Biological Control of
Northeastern Forest Insects and Diseases
Hamden, CT 06514

Abstract

The mortality and growth of dominant, intermediate, and overtopped white pines that had been heavily defoliated were compared with undefoliated trees.

At the end of the 5-year period, following one year of attack by the gypsy moth, 100% defoliation resulted in 28% mortality, 90% defoliation resulted in 8% mortality, while defoliation less than 90% caused very little mortality. Appreciable diameter growth losses occurred in the year of and that following defoliation, and for the 5-year period following defoliation. Managed stands had significantly less mortality and growth loss than unmanaged stands.

Merchantable pine 90-100% defoliated once has a good chance of surviving given normal weather conditions providing it is not badly suppressed. Accepted practices of white pine management such as release from suppression and maintenance of healthy crown and root systems by periodic thinning appear to be effective in greatly reducing losses through mortality and in growth following heavy defoliation.

GROWTH OF EASTERN WHITE PINE: IS IT DECLINING?

James W. Hornbeck - Robert B. Smith

USDA Forest Service
Northeastern Forest Experiment Station
Durham, NH 03824

Abstract

There is increasing concern over effects of acid deposition on eastern forests. The concern is greatest for red spruce for which we have documented a significant growth decline that began about 1960. Much work remains to determine how much if any of this decline is due to acid deposition. In the meantime we have been determining growth patterns for other species, including eastern white pine. Nearly 2,000 white pine trees were cored during 1980-85 as part of the U. S. Forest Service 10-year inventory of New England. The inventory is based on 7,500 plots randomly located across New England. We measured ring widths on all cores using an automated digital micrometer. Our results show that white pine exhibits a trend toward narrowing ring widths in recent years, but that basal area is continuing to increase at a steady rate. White pine does not exhibit a growth decline like that found in red spruce.

PROGRAM OF THE SYMPOSIUM

EASTERN WHITE PINE: TODAY AND TOMORROW

SAF REGION VI TECHNICAL CONFERENCE

Sponsored by

University of New Hampshire
Department of Forest Resources

USDA Forest Service
Northeastern Forest Experiment Station
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Northeastern Area State and Private Forestry

Society of American Foresters
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Ruth E. Farrington Forestry Fund

June 12, 13, and 14, 1985

Durham, New Hampshire

Wednesday, June 12th

OPENING SESSION 1:00 - 2:30 p.m.

WELCOME AND ANNOUNCEMENTS
Theodore Howard, University of New Hampshire

OPENING REMARKS
Raymond L. Erickson, University of New Hampshire
Robert M. Romancier, USDA, FS, NEFES, Broomall, PA

WHITE PINE: THE CASE FOR OPTIMISM
Lloyd Irland, Maine State Planning Office, Augusta

THE TROUBLE WITH WHITE PINE
Robert Marty, Michigan State University, East Lansing

GENERAL SESSION 2:45 - 4:30 p.m.

MODERATOR: J. B. Cullen, New Hampshire Division of Forests and Lands, Concord, NH

THE LORE AND LURE OF EASTERN WHITE PINE
Theodore Howard, University of New Hampshire

INVENTORY AND DYNAMICS
Eric Wharton and Douglas Powell, USFS, NEFES, Broomall, PA

WHERE HAVE ALL THE FORESTS GONE? LONG TIME PASSING
Ernest M. Gould, Harvard University, Petersham, MA

QUALITY ISSUES AND ALTERNATIVES
Jonathan Robbins, Robbins Lumber Co., Searsmont, ME

EVENING TALK AND SLIDE SHOW 8:30 -10:00 p.m.

FIRE AND WHITE PINE IN THE GREAT LAKES REGION: SOME IMPLICATIONS FOR THE NORTHEAST
M. L. Heinselman, St. Paul, MN

COMMENTS: David Olson, University of New Hampshire
MODERATOR: Harold W. Hocker, University of New Hampshire

Thursday, June 13th

MORNING SESSION 8:00 - 11:45 a.m.

MODERATOR: Jane Difley, American Forest Institute, Concord, NH

SOILS - SITE RELATIONSHIPS FOR WHITE PINE IN THE NORTHEAST
William Patterson and Donald Mader, University of Massachusetts, Amherst

WHITE PINE TREE IMPROVEMENT
Louis Zsuffa, University of Toronto, Toronto, Ontario

INFLUENCE OF WILDLIFE ON EASTERN WHITE PINE REGENERATION IN MIXED HARDWOOD-CONIFER FORESTS
Lee Alexander and Bruce C. Larson, Yale University
David P. Olson, University of New Hampshire

GROWTH ESTIMATES IN NEARLY NATURAL WHITE PINE STANDS OVER TWO DECADES
Robert R. Cooke and James Barrett, University of New Hampshire

STOCKING OF WHITE PINE
W. B. Leak, USFS, Northeastern Forest Experiment Station, Durham, NH

CONVERTING TO WHITE PINE AND PLANTATION MANAGEMENT
Clifton Foster, Maine Forest Service, Naples, ME

NATURAL WHITE PINE REGENERATION: SITE REQUIREMENTS
Marshall J. Pecore and Steven T. Heckman, Menominee Tribal Enterprises, Neopit, WI
Kenneth R. Sloan, Wisconsin Department of Natural Resources, Keshena, WI

AFTERNOON SESSION 1:15 - 5:00

MODERATOR: Ralph Nyland, State University of New York, Syracuse, NY

EARLY STAND CULTURE
D. M. Smith, Yale University, New Haven, CT
Robert S. Seymour, Cooperative Forestry Research Unit, University of Maine, Orono

MANAGING WHITE PINE IN ONTARIO
David Wray, Ontario Ministry of Natural Resources, Huntsville, Ontario

ECONOMICS OF THINNING WHITE PINE
Patrice Harou, R. J. Stone, and D. L. Mader, University of Massachusetts, Amherst
Fred Hunt, Sylvan Acres Tree Farm, Reading, VT

PROTECTION:
THE ROLE OF TREE IMPROVEMENT IN PROVIDING PEST RESISTANT EASTERN WHITE PINE
Peter W. Garrett, USFS, NEFES, Durham, NH

ENTOMOLOGICAL PROBLEMS IN GROWING WHITE PINE
Mark W. Houseweart and Fred B. Knight, Cooperative Forest Research Unit, University of Maine, Orono

DISEASES OF WHITE PINE
Charles Hodges, USDA Forest Service, Washington, DC

MARKETING & UTILIZATION:
OHIO WHITE PINE TO SUPPLY MEAD PAPER'S LONG FIBER DEMAND
Walter Smith, Mead Paper, Chillicothe, OH

WHITE PINE MARKETING OPPORTUNITIES
David Schumann, USFS, NA S & PF, Durham, NH

MORE VALUE FOR EVERYONE IN MARKETING EASTERN WHITE PINE
Nicholas Engalichev, Cooperative Extension Service, University of New Hampshire

FRIDAY, June 14th

POSTER SESSION 8:00-9:30 a.m.

Chair: M. T. Demeritt, USFS, NEFES, Durham, NH

MORNING SESSION 10:00 - 12:30

MODERATOR: David Funk, USFS, NEFES, Durham, NH

INDIVIDUAL PERSPECTIVES ON REGIONAL, OWNERSHIP, AND SILVICULTURAL ISSUES

D. M. Smith, Yale University
Robert Chadbourne, P. H. Chadbourne Co., Bethel, ME
Thomas Quink, Massachusetts Dept. of Environmental Management, Boston, MA
Karen Bennett, N. H. Cooperative Extension Service, Milford, NH
Donald E. Martin, Monongahela National Forest, Elkins, WV
Daniel Sims, USFS, S & PF, Atlanta, GA

FIELD TRIP 1:30 - 5:00 p.m.

Sanford - Alfred, Maine

TOUR PLANNING: Kenneth Lancaster, USFS Northeastern Area, S & PF
Richard Weyrick, UNH Dept. of Forest Resources

TOUR LEADERS: Richard Arsenault, Terry Walters, Jeff Smith, Lavalley Lumber Co., Sanford, Maine
Timothy Demeritt, USFS Northeastern Forest Experiment Station

Type Conversion; Route 99 east of Sanford airport

Gordon Prime Woodlot - Intensively managed and privately owned; New Dam Road

Biomass thinning, Bernier Road

Stone Farm, Bernier Road
a) Intensively-managed plantation
b) Natural pine stand-regeneration following 1972 partial harvest

Western white pine research plantings, Massabesic Experimental Forest

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